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Seasonal Changes in the Optical Characteristics of a Hungarian Sodic Lake

by

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(with 3 figs.)

Introduction

Some optical investigations were made in the characteristic, so-called „sodic"* waters of the Great Hungarian Plain. These lakes and ponds have a high sodium content, are shallow but wide, and have a singular, intensive yellowish-brown colour, similar to that of distroph lakes. In windy weather they get stirred to the bottom; their water becomes cloudy (looking like mixed with milk), but sooner or later the turbid water clarifies, mud- and clay-particles precipitate and the water is thus converted again into a transparent yellowish-brown solution. According to Jerlov's investigations (1953, Gessner 1955) the yellowish-brown colour-material of highly humic water is dializible; as the water of sodic lakes behaves similarly, it is a real coloured solution, has a colour of its own and not one produced by colloidal particles, clay, mud, phytoplankton-organisms or detritus, etc., but a dye, dissolved in a molecular distribution from the soil.

The scope of this study includes not only the optical characterization of sodic waters, but also the description of the seasonal changes in their colour and selective light-absorption; and, the evaluation of the optical data from a production-biological point of view.

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* These „sodic" lakes, having a high alkali-content, are very common on the Great Hungarian Plain and can be subdivided into two groups according to chemical characteristics of their water. Lakes of Group A contain carbonate-, as well as hydrocarbonate-ions; lakes of Group B contain no carbonate-, only hydrocarbonate-ions, and are called „*carbonate-type sodic waters*" and „*hydrocarbonate-type sodic waters*", respectively.

Method

Investigations concerning selective light absorption were made by an indirect way. During the laboratory investigation of natural waters, either Pulfrich-type photometers (Gärtner, 1929; Entz, 1950) or spectrophotometers (Aufsess, 1903, 1904; James, 1939; Knudsen, 1922) have been used. In the present research the selective lightabsorption of the waters has been determined by a Hilger-type U. M. monochromator. The accuracy of this method is superior both to visual and cell-photometers. Only the measurements of Clarke & James (1939) were carried out with strictly monochromatic light in marine waters; data on monochromator investigations in fresh waters are not to be found in literature available in Hungary.

A wide spectrum in monochromators is produced by the aid of a prism; the rays of the desired colour and purity can be easily limited out from this spectrum. It is essential, that a constant-colour and constant-intensity light should be used to avoid the irreproducibility of measurements. The constancy of light in both respects was assured by double control; an accumulator was the power source instead of the fluctuating line voltage as a first, and the supply circuit was hold on constant current by means of a regulating resistor and ampère meter as a second control. As a result of these precautionary measures, all data were completely reproducible.

2 cm thick cuvettae were used during measuring quantitative absorption at various wavelengths. Measurements were repeated several times and their accuracy proved. Comparative data of chemically pure water were calculated on the basis of Aufsess' (1905) measurements.

When determining the absorption of light at a given wavelength, the intensity of light is measured, after its having passed a layer of given width. The basis of measurements is Lambert's law:

$$I_l = I_o \, . \, e^{-\alpha . l}$$

or

$$\alpha = \frac{1}{l} \text{ lognat } \frac{I_o}{I_l}$$

The meaning of symbols:

α – Lambert's coefficient of extinction

I – intensity of light, after passing a layer of width 1 cm

I_o– intensity of incident light

During this investigation Bunsen's coefficients of extinction were calculated.

The use of Bunsen's coefficient of extinction (instead of Lambert's), introduced by Poole & Atkins (1926) and used till now only in

limnology is more practical. The calculation of the former (based on decimal logarithms) is simpler and it gives more valuable data than the latter (based on natural logarithms). The reciprocal values of both coefficients give a measure of change of light-intensity with the depth; but while the reciprocal of LAMBERT's coefficient gives the depth, where light intensity is the $1/e$ part of incident intensity, the reciprocal of BUNSEN's coefficient gives the depth, where the incident intensity of light is weakened to its one-tenth. This latter value is, naturally, more practical and can be used without any conversion to further calculations (DVIHALLY, 1958).

GENERAL CHARACTERISTICS OF SELECTIVE LIGHT ABSORPTION OF SODIC WATERS

The run of the absorption curves of sodic waters has just an opposite direction, as compared with the absorption curve of pure water. (The selective absorption of sodic waters of several sodic lakes and ponds of the Great Hungarian Plain has been investigated in detail by DVIHALLY, 1958). The main result of this investigation was, that while a 200 m thick layer of pure water is needed to absorb 90 % of incident blue rays, a 0,1—0,2 m thick layer of sodic water is enough to produce the same measure of absorption. Pure water transmits red light in the smallest measure, sodic water in the largest.

The selective light-absorption of sodic waters differs from that of marine, as well as of fresh waters, examined till now. Investigations of REGNARD (KRÜMMEL, 1907), COLLINS (1925) CLARKE & JAMES (1939), DIETRICH (1939), ATKINS et al. (1938), JORGENSEN & UTTERBACK (1939) etc. have proved, that the absorption of marine waters is the highest in the red and the lowest in the blue section of the visible spectrum.

The selective light-absorption of sodic Hungarian waters cannot be fitted into either category of AUFSESS's (1903) classification. The characteristics of his first, second and third category are completely different from those of sodic lakes and the fourth category (type *Staffelsee*) is approached only by the fact, that the latter absorbs also blue rays totally, but differs in the region of highest transmission. The water of Lake *Balaton* shows the greatest transparence for rays of yellow and green spectral region (GÄRTNER, 1929; FELFÖLDY & KALKÓ, 1958). In the water of the river *Danube*, quantitative transparence depends on the quantity of suspended matter; from a merely qualitative point of view, however, yellowish-green light rays show the greatest transmission (DVIHALLY, 1959 a and b). Blue or green rays pass deepest in clear, transparent waters (e.g. *Crater Lake*,

Oregon or *Crystal Lake*, Wisconsin, respectively); in waters, having a medium transparence and a tint, seen even by an unaided eye, the yellow colours (e.g. *Lunzer Untersee*; HUTCHINSON, 1957). Only few, occasional data are found on some waters of absorption curves with a similar run to Hungarian sodic waters; i.e. rays with a high wavelength penetrate into their deepest layers because of their high brownish dye content (*Lake Mary*, Wisconsin; *Helmet Lake*, Wisconsin; BIRGE & JUDAY, 1931; and some lakes of Northern Europe, ÅLVIK, 1934).

SEASONAL CHANGES OF SELECTIVE LIGHT-ABSORPTION IN THE WATER OF A SODIC LAKE

To determine optical properties and seasonal changes of a water of this type examinations have been made on a characteristically sodic lake (carbonate-type sodic) of the Hungarian Great Plain; this lake, (the Lake *Nagyszéktó*) is located in Southern Hungary, near Kistelek. The selective light-absorption and chemical constitution of the water of this lake has been determined every month for a year. Chemical data have been published already (DVIHALLY, 1960); thus only results of optical investigations and a few, more important chemical composition figures need to be given here.

The extinction coefficients of the water show a great variability in the course of one year. These changes are caused by the changes of humic acid content, getting into the water from the luxuriant vegetation of the shores and litoral waters. Humid acid is dissolved in the alkalies of the water. Ca- and Mg-salts, on the contrary, precipitate organic matter in form of badly soluble calcium- or magnesium humate, respectively; the transparent yellowish-brown colour of the lake gets paler this way.

The absolute organic matter quantity is high in summer; which, combined with high sodium content (80—90 equival. per cent) yields a high content of colouring material. This remains dissolved, if the quantity of alkaline earth salts is not high (this is the fact in sodic waters during summer months, when the dissolved Ca-ion content is small, sometimes even undeterminable).

The colour of the sodic waters fades in winter. This can be explained by the decrease of organic material on the one hand and the increase of Ca-ions on the other. The latter phenomenon is caused by the decrease of intensity of the assimilation process; consequently the equilibrium between differently bound sorts of CO_2 changes and thus the CO_2 content of water is increased. This increase is supported also by an other CO_2-source: the decomposition of vegetation. As the CO_2-content of the water increases, a higher quantity of Ca-ions

TABLE I.

Variation of extinction coefficients (β) in the water of Lake Nagyszéktó during one year. (1955).

ÅU	January	February	March	April	May	June	July	August	September	October	November	December
4500	0,031	0,031	0,026	0,056	0,058	0,096	0,101	0,131	0,113	0,093	0,083	0,048
4700	0,029	0,030	0,026	0,056	0,058	0,073	0,079	0,105	0,100	0,080	0,082	0,048
4900	0,027	0,028	0,026	0,055	0,055	0,057	0,062	0,095	0,070	0,060	0,070	0,044
5100	0,027	0,028	0,025	0,050	0,053	0,050	0,047	0,078	0,045	0,050	0,060	0,043
5300	0,025	0,025	0,024	0,046	0,053	0,048	0,043	0,066	0,031	0,036	0,045	0,039
5500	0,024	0,024	0,025	0,043	0,050	0,048	0,034	0,048	0,020	0,032	0,039	0,036
5700	0,023	0,024	0,024	0,040	0,045	0,034	0,034	0,037	0,020	0,022	0,028	0,034
5900	0,021	0,022	0,023	0,036	0,043	0,037	0,033	0,026	0,016	0,017	0,025	0,028
6100	0,020	0,021	0,022	0,034	0,042	0,018	0,019	0,015	0,014	0,016	0,023	0,024
6300	0,019	0,020	0,021	0,034	0,037	0,020	0,017	0,016	0,011	0,012	0,016	0,020
6500	0 018	0,019	0,021	0,031	0,036	0,012	0,012	0,009	0,009	0,011	0,013	0,019
6700	0,017	0,019	0,020	0,028	0,035	0,010	0,009	0,007	0,008	0,009	0,013	0,018
6900	0,017	0,019	0,020	0,025	0,036	0,009	0,009	0,006	0,007	0,008	0,013	0,018

TABLE II.

Values of $1/\beta$, of Na^{+}-, Ca^{++}- and Mg^{++} content (equivalent percentages) and of red/blue ratio of the water of Lake Nagyszéktó during one year (1955).

ÅU	January	February	March	April	May	June	July	August	September	October	November	December
4500	32,2	32,2	38,5	17,9	17,2	10,4	9,9	7,6	8,8	10,7	12,0	20,8
4700	34,4	33,3	38,5	17,9	17,2	13,6	12,6	9,5	10,0	12,5	12,2	20,8
4900	37,0	35,7	38,5	18,2	18,2	17,5	16,1	10,5	14,3	16,7	14,3	22,7
5100	37,0	35,7	40,0	20,0	18,9	20,0	21,3	12,8	22,2	20,0	16,7	23,3
5300	40,0	40,0	41,6	21,7	18,9	20,8	23,3	15,1	32,2	27,7	22,2	25,6
5500	41,6	41,6	40,0	23,3	20,0	20,8	29,4	20,8	50,0	31,3	25,6	27,7
5700	43,5	41,6	41,6	25,0	22,2	29,4	29,4	27,0	50,0	45,4	35,7	29,4
5900	47,6	45,4	43,5	27,7	23,3	27,0	30,3	38,5	62,6	58,8	40,0	35,7
6100	50,0	47,6	45,4	29,4	23,8	55,5	51,8	66,7	71,4	62,6	43,5	41,6
6300	52,6	50,0	47,6	29,4	27,0	50,0	58,8	62,6	90,9	83,3	62,6	50,0
6500	55,5	52,6	47,6	32,3	27,7	83,3	83,3	111,0	111,0	90,9	76,9	51,8
6700	58,8	52,6	50,0	35,7	28,6	100,0	111,0	142,8	125,0	111,0	76,9	55,5
6900	58,8	52,6	50,0	40,0	27,7	111,0	111,0	166,7	142,8	125,0	76,9	55,5
$Ca^{++} + Mg^{++}$ equ. %	36,99	34,79	43,01	23,28	21,23	13,77	16,77	8,88	10,70	13,18	26,05	27,58
Na^{+} equ. %	63,01	65,21	56,79	76,72	78,97	86,23	83,23	91,12	89,30	86,82	73,95	72,42
red/blue ratio	1,8	1,6	1,3	2,2	1,6	10,7	11,2	22,0	16,2	11,7	6,4	2,7

gets into solution, causing the precipitation of humic compounds.
This is why the yellowish-brown colour of sodic lakes fades rapidly beginning with the autumn months. By winter there remains only a faint nuance of summer colour; with spring the intensity of colour begins to increase again. Extinction values run parallel with colour intensity.

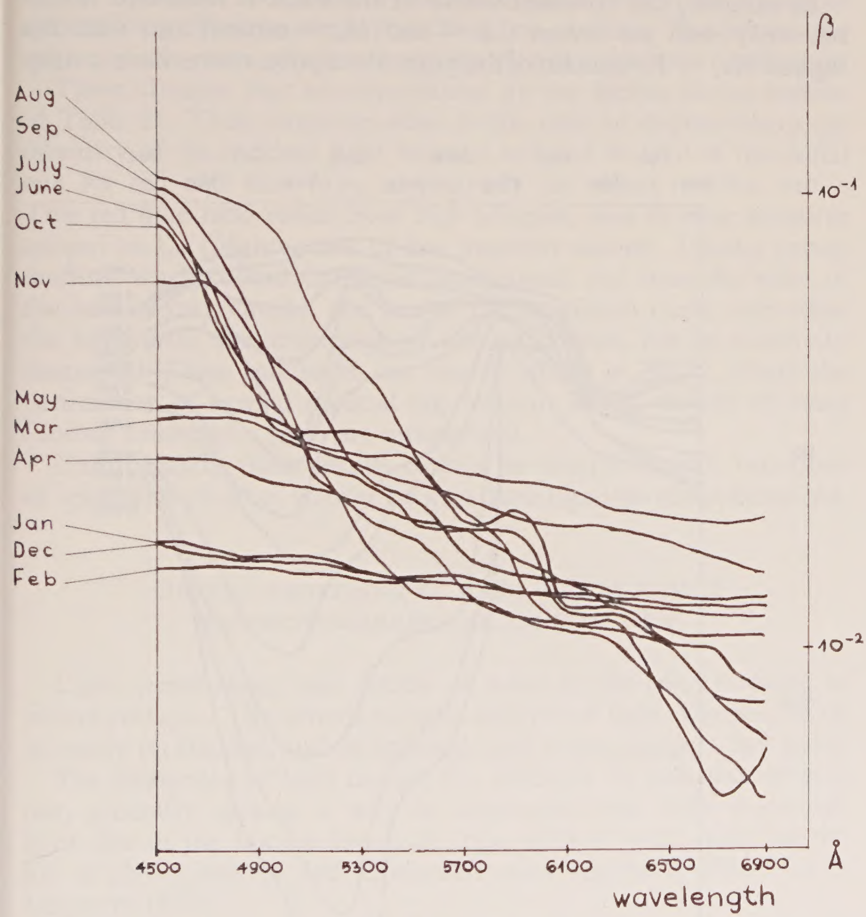

Fig. 1. Absorption curves of the water of Lake Nagyszéktó.

Table I gives the extinction coefficients of the water of Lake *Nagyszéktó* throughout a year. Absorption curves, constructed from these data are shown in Fig. 1. The various run of absorption curves is clearly visible; the changes of optical conditions in a year are well seen from the shape and slope of the curves. Table II gives values of

$1/\beta$ (i.e. the width of the water-layer due to the weakening of light-intensity to 1/10 of its initial) and further data of alkali-, Ca^{++}-and Mg^{++}-content (in equivalent percents) measured simultaneously with optical investigations.

By comparing Fig. 1, Tables I and II the direction and degree of changes is well seen:

In summer, the brownest colour of the water is measured simultaneously with the lowest Ca^{++}- and Mg^{++}-content and with the highest $Na^{+} + K^{+}$ content of the year. Absorption curves have a steep

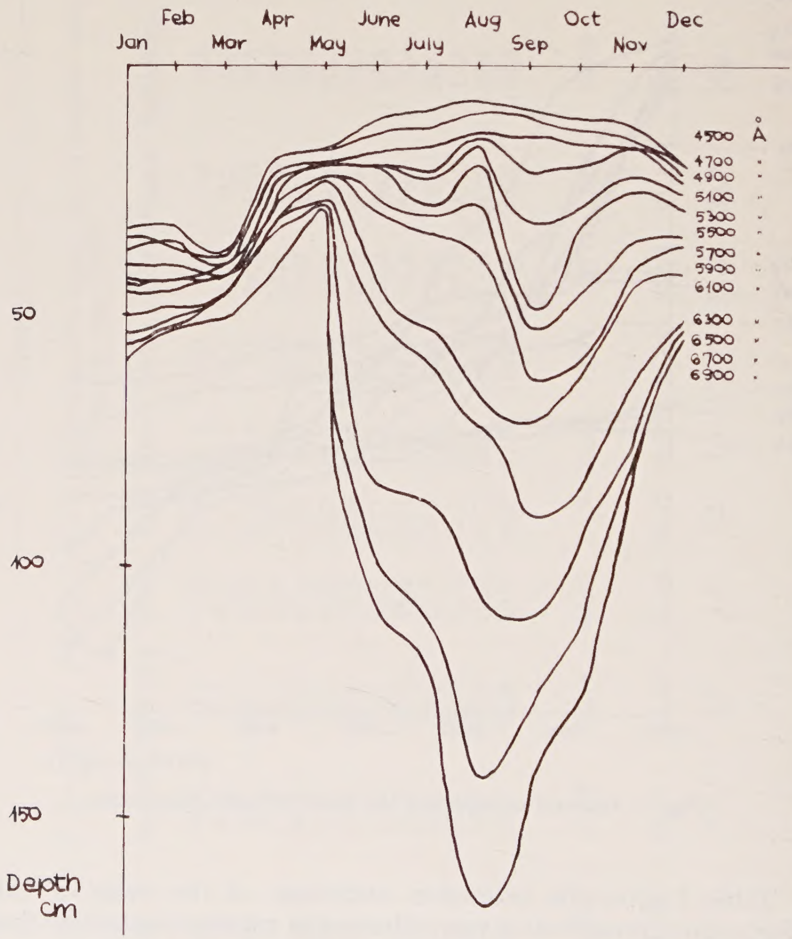

Fig. 2. The penetration of several spectral regions into several depths of the water of Lake Nagyszéktó.

run in these cases. The more intensive the colour of the water, the thinner is the layer absorbing blue, and the thicker the one absorbing red rays.

The „fading" of the yellow colour of water does not affect shade; it becomes only „dissolved" (i.e. its white-content increases).

After the summer months, the transmission of blue, or red regions of the spectrum increases, or decreases, respectively; the values of extinction coefficients are approaching one another. The fainter the colour of the water, the less steep the plot of extinction coefficients.

These changes best are reproduced by the figures at the bottom of Table II. These numbers refer to the ratio of depths where the intensity of the incident light beam is reduced to 1/10 of the initial one for red and blue rays, respectively (so called *red/blue ratio*). This red/blue ratio varies from 22,0 (August, case of most intensive colour) to 1,3 (March, case of less intensive colour). During spring months, when colloid $CaCO_3$ is precipitated, and thus the water of the lake is very cloudy, the run of the extinction curve approches the horizontal: the absorption of water increases, but its selectivity decreases! These conditions are clearly visible in Fig. 2, where the penetration of several spectral regions into several depths of water (during course of a year) are represented.

Unfortunately these results cannot be compared with variations of selectivity of other waters, because investigations are outstanding.

Optical properties of sodic waters from a production-biological point of view

Light penetrating into depths of water is the energy-source of photosynthesis. The photosynthetic activity of light depends on its intensity on the one, and its spectral constitution on the other hand.

The weakening of light intensity is different for each wavelength; but, generally spoken, it may be concluded, that there is enough light also in the bottom layers of these shallow sodic lakes for the life of phytoplankton and submersed water vegetation (Pearsall & Ullyott 1933).

The spectral composition of the light changes, when penetrating into water. In lakes of clear water the absorption of the shortest wavelengths of the visible spectrum is the lowest; i.e. blue light reaches deepest layers, (just as in the waters of oceans). Sodic lakes, on the contrary, rapidly absorb light and last rays have long wavelengths.

Fig. 3 shows spectral constitution of surface light and the light of various depths of lakes with different optical characteristics, accor-

ding to HUTCHINSON (1957). The optical conditions of Lake *Nagyszéktó* are also shown for the sake of comparison. The spectral composition of the light, reaching various layers of Lake *Nagyszéktó* are not calculated from month to month, but it is obvious from the values of extinction coefficients, that red/blue ratio is increased in the deeper layers of sodic waters. In the course of one year, only red light carries energy into sodic waters after a certain depth. But, according to investigations of JOST and ENGELMANN (MAUCHA, 1924) it is just red light (with wavelength between 6300—6700 ÅU) which is most effective with regard to photosynthesis. This is the cause of trophity and extraordinarily high productivity of sodic waters.

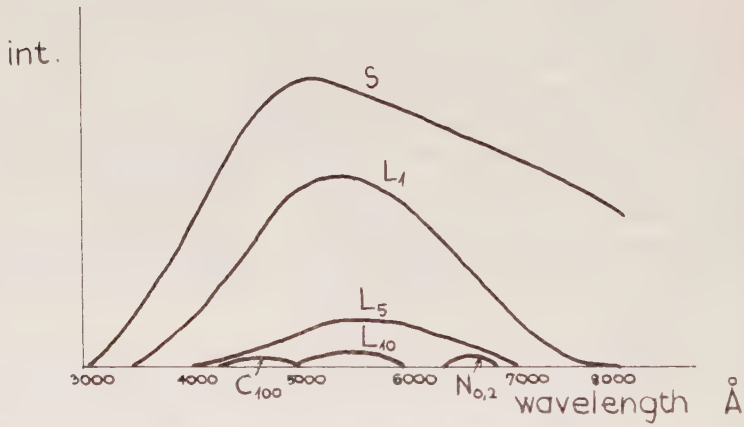

Fig. 3. Spectral composition of surface light and light in various layers of several lakes with different optical characteristics (approximative data). Symbols: S = surface, L = Lunzer Untersee, C = Crater Lake, N = Nagyszéktó-Lake. Indices refer to depths (in meters). (Partly after HUTCHINSON).

SUMMARY

The selective light-absorption of a typically „*sodic*" water (Lake *Nagyszéktó*, Great Hungarian Plain) and its changes during a year have been determined by monochromator measurements. It has been found, that in all seasons the rays of the red spectral region have the lowest extinction coefficient (i.e. these rays penetrate to the deepest layers: after a certain depth, only red light carries energy). But just this spectral region has the greatest photosynthetic activity. This gives an explanation for the trophity and extraordinarily high productivity of sodic lakes.

Zusammenfassung

Die selektive Lichtabsorption eines typischen Natronwassers (*Nagyszéktó-See*, Ungarn, Grosse Tiefebene) sowie die Änderungen desselben während eines Jahres wurden mittels Monochromator gemessen. Es wurde festgestellt, dass der Extinktionskoeffizient der roten Strahlen der geringste ist, und zwar in allen Jahreszeiten. Diese Strahlen dringen in die tiefsten Schichten ein; nach einer bestimmten Tiefe sind nur die langwelligen Strahlen Energieträger. In diesem Gebiet ist die stärkste photosynthetische Aktivität zu beobachten, welcher Umstand die hohe Trophität und Produktivität der Natrongewässer erklärt.

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On Some Aspects of the Natural Occurrence of Chirocephalus diaphanus Prévost

by

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(with 2 figs.)

INTRODUCTION

Chirocephalus diaphanus PRÉVOST has long been known in England, where it has been recorded from a number of localities. It always occurs in temporary bodies of fresh water, and though its sporadic occurrence has often been noted and commented on, no systematic observations on its appearance and dissappearance, and the relationship between these phenomena and changes in the wetness of the habitat have been recorded. The fact that its eggs are able to withstand desiccation has frequently been demonstrated, and it is said that this property of the eggs enables the animal to survive unfavourable conditions such as the complete drying out of the habitat in which it occurs.

This mechanism would suffice to explain the intermittent appearances of *Chirocephalus* if it was necessary for the eggs to be dried before development could be completed and hatching occur. However, as LOWNDES (1933) has pointed out, it has often been demonstrated that desiccation is not a prerequisite for development. The author (HALL, 1953) further confirmed that the eggs do not need drying for development to be completed. No explanation has so far been given as to how eggs which subsequently live through unfavourable conditions are prevented from hatching if laid some time before the unfavourable conditions supervene.

It was with a view to elucidating the method by which eggs laid

when the habitat was filled with water are prevented from developing while conditions are still apparently favourable that the author carried out a series of investigations of the factors affecting the hatching of eggs. The results of some of these observations have been reported elsewhere. At the same time a long-term series of observations on the appearance and disappearance of *Chirocephalus* in the field, and the relation between these phenomena and habitat changes, were initiated. In this paper the results of these field observations are presented and discussed in the light of the experimental findings referred to above.

The habitats of chirocephalus diaphanus

Observations were carried out in two separate localities on two habitats of slightly different characteristics. The first was a pond situated at Burley in the New Forest which has previously been described by the author (Hall, 1953). Briefly, its chief characteristics are that it is fairly large, being roughly circular in form and approximately 30 m in diameter and reaches a depth of between 50 and 70 cm when full. The substratum is grassy and the water generally clear. Observations on this pond extended over a period of more than six years.

The second locality was at Lee, near Romsey in Hampshire, and the site consisted of a muddy depression, frequently trampled by cattle, lying at the side of a gravel road, opposite the entrance to a farmyard. The depression was about 40 m long and 4 m wide, and when completely filled consisted of a single sheet of water of perhaps 15—30 cm deep. As it dried out the water became separated into large isolated patches and puddles a few centimeters deep, the final stages before complete drying out being in the form of isolated hoof-marks in the mud with about 2—3 cm of water in them. Because of frequent trampling the water was at times opaque and thickly muddy. When the mud settled the depressions were shallow enough to enable even small living organisms to be observed with certainty.

Methods

Both ponds were visited at intervals of in general not more than two or three weeks, though periodically more frequent visits were made. A note was made of the extent to which the ponds contained water. Due to the variation in depth of the Burley pond in various parts and also to the fact that Lee pond was periodically trampled by

cattle it was impossible to obtain exact figures for depths. Records were kept in approximate terms such as full, three-quarter-, half- and quarter-full and empty in the case of the Burley pond. As pointed out previously, at low levels Lee pond became a series of isolated puddles.

Whenever any water was present careful search was made for *Chirocephalus*. Although Burley pond was deep, the water was always fairly clear and, if viewed in a good light it was possible to say with reasonable certainty whether *Chirocephalus* was precent or not, though it was not possible to prove a definite negative. Since however, whenever specimens of *Chirocephalus* were seen, they were noticed very rapidly and with little difficulty, it seems a reasonable assumption that if no traces were found after prolonged search, there were no specimens present.

In Lee pond the extent and depth were more limited and when the water was clear it was possible to say with certainty whether specimens were present or not. When the water was muddy after recent trampling it was not possible to see any animals.

During the cold spells in the winter the water in the ponds sometimes froze; the effects were different in the two ponds. Due to its depth the Burley pond never froze solid; even in the longest and most intense cold spells the ice did not attain a thickness of more than three inches, so that a good volume of unfrozen water remained below the ice. At Lee, particularly when the pond was partially filled or nearly empty, all the water froze and there remained only frozen mud below the ice. It will be seen that this difference affected the survival of *Chiroceophalus*.

Results

The respective records of the two ponds are illustrated by Figs. 1 and 2. The heights of the columns in the histograms represent the depth of water, as recorded in the approximate terms referred to above. The presence of *Chirocephalus* in immature or mature stages is indicated in the upper part of the figures.

Burley pond:

The record, which extended from March 1950 to June 1956, clearly illustrates the sporadic occurrence of *Chirocephalus*. Thus, after its sudden disappearance in November 1950 it was not seen again until September 1952, in spite of the long period at the beginning of 1951, lasting for six months, when the pond contained water. Even with the intervention of two dry spells it did not occur during

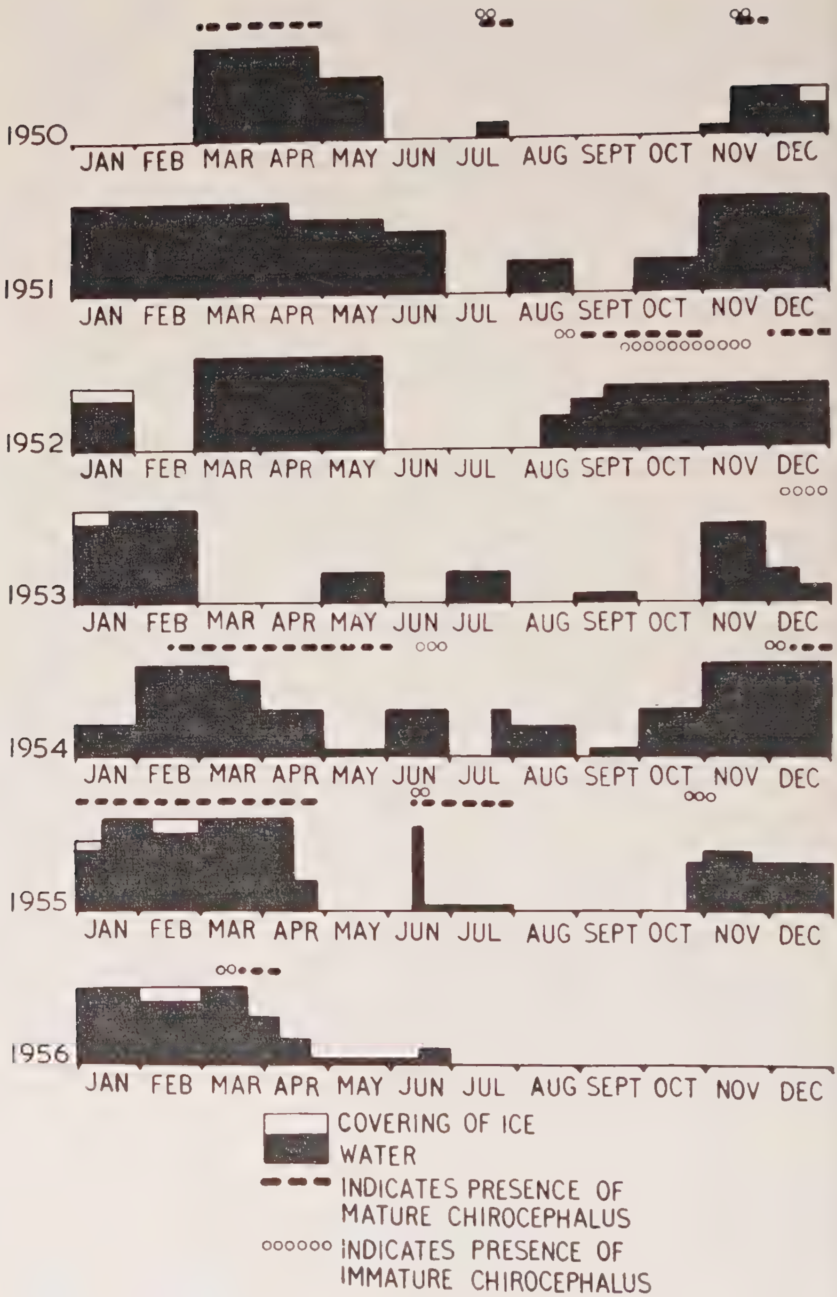

Fig. 1. The occurrence of *Chirocephalus* in Burley Pond during the period 1950—56.

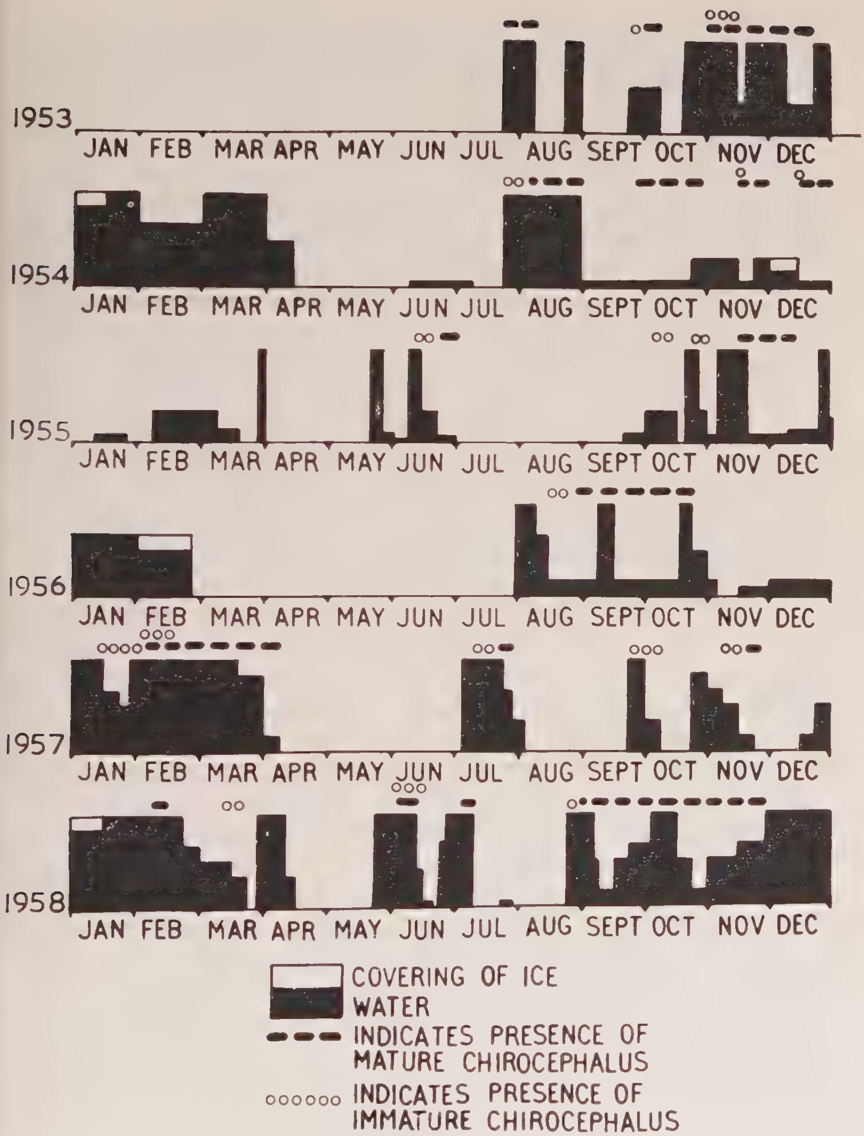

Fig. 2. The occurrence of *Chirocephalus* in Lee Pond during the period 1953—58.

the subsequent wet periods. There was a further blank period of over a year in 1953, while in the spring and early summer of 1954 it was present continuously for over four and a half months. In spite of several dry intervals specimens were recorded during seven months of 1955. August was the only month in which *Chirocephalus* was never recorded from this pond.

Because of its depth the pond did not dry out frequently or quickly. Thus it can be seen that the general pattern was for the pond to remain partially or completely filled in the first four or five months of the year, then to dry up, with perhaps a brief wet period during the months of June, July, or August. In general when it became refilled in the autumn it did not dry again until the late spring.

Lee Pond:

The record in this case covered the period from July 1953 to December 1958, and it once again very clearly illustrates the intermittent presence of *Chirocephalus*. The record differs from that of the Burley pond in that there were no long-term disappearances: records were obtained during every year. Once again it was taken during eleven of the twelve months, in this case May being the only month in which no specimens were seen. It is clear from the record that in four of the six instances the habitat was dry throughout May and in the other two years it was dry except for about a week.

The appearances and disappearances tended to be rather more numerous; this reflects the rather more frequent drying out of the habitat. The pattern in the early part of the year was not dissimilar to that shown by Burley pond: in general the habitat contained some degree of tree water for the first three or four months of the year, while on the whole the period May-July was one of drying out. The period of autumn and early winter tended to be more broken: this probably reflects the fact that the maximum depth of the pond was comparatively small. It will be seen that typically four or five generations were recorded during the year. This phenomenon is similar to that described by Moore (1955) for *Streptocephalus seali* in America. Moore recorded a maximum of seven separate occurrences of this species in a period of twelve months.

Discussion

The results in Figs. 1 and 2 show the periods during which the ponds contained free water and also the times at which specimens of *Chirocephalus* were found. In attempting to relate these two sets of data several factors must be considered. Two factors are obviously

important in determining the period elapsing between the establishment of free water and the occurrence of mature specimens. These are, firstly the length of embryonic development and secondly the length of larval development.

Two other factors must be considered, since they may lead to an apparent reduction in the total developmental time. They are, firstly the question of whether any development takes place immediately the eggs are laid and before drying out of the habitat occurs, and secondly whether any embryonic development occurs during periods of desiccation.

The question of whether, under natural conditions, eggs develop while lying at the bottom of a pond, or whether development is suspended or retarded until drying up occurs, will clearly be important in determining whether viable eggs will remain unhatched until unfavourable conditions have come and gone. The speed with which maturity is reached, once favourable conditions have again been established, will also be important in a form living in habitats which may remain favourable for only short periods of time.

The relationship between the freezing of water in ponds and the survival of *Chirocephalus* under these conditions will be discussed in the light of observations in the field and in experimental tanks.

The Rate of Embryonic Development.

Information on the rate of development of the egg in water is available from a number of sources. BAIRD (1849) and WADDINGTON (1915) both give two weeks as the time taken by eggs to hatch, though they give no details of the temperature at which this development occurred. MATHIAS (1926) quotes a period sixteen to seventeen days at a temperature of 15 deg. C. and thirteen to fourteen days at 18 deg. C. The author (HALL, 1953) obtained a figure of fourteen days at 15 deg. C. and later (HALL, 1959a) obtained indications that at a temperature of 22 deg. C. hatching probably occurred after nine to ten days, since the break in the outer covering appeared after about seven days. While no information is as yet available as to the rate of development at slightly lower temperatures, it has been shown by the author (HALL, 1959b) that at 2 deg. C. the rate of development is abouth 1/7th of that at 15 deg. C. The normal rate for development in the winter is probably intermediate between these figures, while that for the summer may be taken as being approximately fourteen days.

It is clear therefore that, where eggs can be shown to have hatched before the necessary period of fourteen days has elapsed, some partial development must have occurred either during the period for which the pond was dry, or before drying up occurred. Thus the author

has several times found that when dried mud is placed in a vessel and covered with water, nauplii appear within two or three days.

The length of larval development.

The author (HALL, 1953) described field observations which showed that *Chirocephalus* could develop to maturity within a period of three weeks. The data for Lee pond shown in Fig. 2 support these observations. Lee pond was known to be dry on June 18th, 1958. During that night and the next there was heavy rain: on June 22nd the pond was half-filled. Further rain during the next two weeks kept it filled and on July 6th large mature specimens of *Chirocephalus* were taken. Thus complete development from hatching to mature adult had occurred in a period of fourteen to sixteen days. It isclear that hatching must have occurred almost immediately after flooding, and that embryonic development must have been completed either during the preceding dry period, or before drying out of the habitat was complete. MOORE (1955) reports a similar rapid development of *Streptocephalus seali*: he found the interval between flooding of the habitat and attainment of sexual maturity to be no more than nine days, and that hatching occurred within thirty hours of flooding.

The development of eggs in the absence of water.

Little direct information on this question is available. The author (HALL, 1953) obtained some indication that when eggs were kept dry in a watchglass over a period of several weeks, some slow development occurred. However, further observations failed to give any very clear indications on this point. Eggs which had been kept dry for a period of about six weeks developed in the normal way when returned to the water, but eggs kept dry for longer than this failed to develop on return to water. MOORE (1957) obtained rather similar resultswith eggs of *Streptocephalus seali*. He found that eggs kept in dried mud appeared reasonably viable up to a period of about four weeks, but that eggs kept in this way for longer periods failed to hatch. Clearly further work is necessary to elucidate this point. It seems possible that the degree of desiccation to which the eggs are subjected may be significant.

Tge development of eggs before drying-up of the habitat.

Consideration has so far been given to the time required for embryonic and post-embryonic development after water has reappeared in the habitat, and also to the possibility of embryonic development continuing under dry conditions. Consideration must now be

given to the question of whether any embryonic development occurs immediately after the eggs have been laid and before the habitat becomes dry. In all the numerous occasions on which the author has recorded and observed the occurrence of *Chirocephalus* in the field, there have been only two cases in which there was any evidence of the development of a second generation in the same wet period as the first. In view of the short period required to reach maturity and the fact that mature specimens have been known to exist in a pond over a period of two or three months, it might be expected that, unless there was some retardation of development, hatching of a second generation would occur where water persisted for about two months or more. The fact that the occurrence of a second generation is so infrequent suggests that some factor may inhibit or retard development. In the two cases in which a second generation developed without complete drying out of the pond, there was a period in which the water level fell considerably. It is possible that eggs laid near the margin would be subjected to drying or near drying and that with refilling of the pond these would hatch and so give a second generation. DEXTER & KUEHNLE (1951) reported a comparable phenomenon in connection with *Eubranchipus vernalis*. When the pond fills up rapidly early in the season there is only one generation, but with gradual filling several generations were found. NOURISSON (1959) working on *Chirocephalus stagnalis* states that each generation is separated from the next by a period of drying up.

The author (HALL, 1959a) found that eggs left in the detritus of a large aquarium jar did not hatch and commented on the fact that in general no traces of larval stages were found in laboratory aquaria in which it was known that viable eggs were being laid. In this, and in a further paper (HALL, 1959c) it is suggested that this delayed development is correlated with the depth of water overlying the eggs. It may well be that cessation of development while eggs are submerged by an appreciable depth of water ensures that they remain unhatched until the final stages of drying, so avoiding being killed off before they can reach maturity and reproduce. This point is discussed further below.

The conditions under which eggs do and do not develop.

The author (HALL, 1953) showed that eggs kept in shallow water (less than 1 cm deep) in watchglasses would complete development in about fourteen days. It was also shown (HALL, 1959c) that at depths of over 20 cm there was very little if any development, while there was some evidence that at intermediate depths development occurred slowly.

The conditions to which eggs may be successively subjected during the course of the drying up of a pond, during the succeeding dry period, and finally during and after the course of refilling may now be considered in the light of the findings referred to above.

When laid, the eggs, which are relatively dense, fall to the bottom, where they lie in the loose material of the substratum. The evidence, both of laboratory and field observations, indicates that so long as the depth of water remains greater than about 20 cm no development will occur. When drier conditions supervene and the depth of water becomes reduced by evaporation slow development probably begins. The extent to which this development proceeds will depend upon the length of time for which the water remains shallow. For development to be completed and hatching to result a period of at least fourteen days of very shallow conditions would be needed. In general, if the water were reduced to such a depth it would evaporate to dryness in about a week under normal summer conditions, leaving partially developed eggs in the dried up substratum. This point was tested by noting the rate of evaporation from a large flat dish in the open air in the summer. Under dry sunny conditions a depth of 3.5 cm of water dried out in a period of nine days.

During the period of desiccation it is probable that if any further development occurs it is very slow: as was pointed out above, there is no conclusive data on this.

When rainy weather brings an end to the dry conditions and the substratum becomes covered with a shallow layer of water development is resumed and the eggs may reach the stage at which rupture occurs in a comparatively short time. As was pointed out above, nauplii may appear within forty-eight hours of wetting of the eggs.

The phenomenon of delayed hatching, described by the author in an earlier paper, may be further considered at this point. It was noted that on a number of occasions eggs developed to the point at which rupture of the outer covering occurred, but that this was not followed by hatching. It was found frequently that the eggs could be kept for several weeks in this state, and that rupture of the inner membrane and hatching could be induced by the addition of distilled water. It was suggested that this was an osmotic phenomenon and it is now further suggested that this capacity of the fully developed embryo to remain unhatched may have some survival value. Immediate hatching of fully developed embryos after the first wetting of the ground might lead to the starting of larval development before there was sufficient water for it to be completed. A device which would prevent hatching until more water was present might ensure a better chance for the larvae to develop to maturity and lay a further batch of eggs before the habitat dried out again. It is suggested

that some reduction of osmotic pressure of the pond water might occur as a result of dilution with rain water, so ensuring hatching as the volume and depth increased.

The effect of freezing of the habitat.

The data on freezing of the habitats recorded in Figs. 1 and 2 will be considered in relation to some observations made in the laboratory and in an experimental tank. It can be seen that while in certain cases the freezing over of the water surface was correlated with the disappearance of *Chirocephalus*, in some instances a population was maintained for several weeks beneath the ice sheet.

In the course of a severe cold spell during the winter of 1955—56 a number of *Chirocephalus* were placed in a tank on an open flat roof. Although a sheet of ice several inches thick formed over the water, a small hole a few inches in diameter was made in it daily to allow access of air. Although this covering of ice lasted continuously for three weeks the population lived through this period without any noticeable mortilaty. The findings of DEXTER & KUEHNLE (1948) working on *Eubranchipus vernalis* are somewhat similar. They found this species living under ice for at least three weeks under natural conditions. It disappeared when the condition of the water deteriorated.

Two small laboratory tests gave further support to the suggestion that *Chirocephalus* can survive comparatively low temperatures. In the first case a batch of one hundred freshly hatched nauplii were kept in water at 0 deg. C. for twenty-four hours. All but six continued their normal activity when returned to normal laboratory temperatures. A further group of twenty nauplii were subjected to a temperature of 0 deg. C. for forty-eight hours. Of these thirteen survived.

It seems likely that low temperature is likely to prove lethal only when all the water in the habitat freezes. When there is an adequate supply of water below the ice there is no evidence that freezing of the surface will eliminate a population of *Chirocephalus*. Complete freezing is much more likely to occur in shallow pools such as Lee pond: the larger number of generations in this habitat in the course of the year have already been commented upon.

The probable sequence of events which results in *Chirocephalus* surviving unfavourable conditions and quickly re-establishing a population after the advent of favourable environmental conditions may be summarized as follows. The eggs remain undeveloped while the habitat remains filled with water. As it dries out some embryonic development will occur, the actual amount depending on speed of evaporation and the degree of their subjection to shallow water conditions. In general drying out will occur before development is

complete. Some further slow development may occur under dry conditions. Rewetting of the eggs will allow development to proceed to the hatching point, though hatching itself may be prevented until there is some dilution of the water.

SUMMARY

1. The occurrence of *Chirocephalus diaphanus* PRÉVOST in two habitats of somewhat different character is described from observations extending over a number of years.

2. The records in both cases underline the sporadic and irregular occurrence of this species.

3. The number of generations occurring during the course of a year appears to be related to the frequency with which the habitat dries out or is subjected to other unfavourable conditions. In general a second generation does not overlap the first and only appears when the habitat becomes wet again after an interval of drying out.

4. The pattern of natural occurrence is discussed in the light of experimental work on conditions affecting development and hatching of the eggs.

5. A sequence of events is suggested by which viable eggs are enabled to remain unhatched while the habitat dries out, to survive desiccation, and finally to complete development to maturity in a very short period.

6. The possible effects of freezing of the habitat are discussed.

RÉSUMÉ

1. La présence de *Chirocephalus diaphanus* PRÉVOST dans deux habitats d'un type légèrement différent est décrite, basée sur des observations faites durant plusieurs années.

2. Dans les deux cas les données montrent la présence irregulière et sporadique de cette espèce.

3. La quantité des générations qui se trouvent pendant un an est manifestement en relation avec la fréquence avec laquelle l'habitat se desséche, ou se trouve dans des conditions défavorables. Ordinairement une seconde génération ne chevauche pas la première génération; elle ne se présente qu'après un intervalle de dessèchement.

4. Le schema de la présence naturelle est discuté en comparaison avec les investigations expérimentales, des conditions qui influencent le développement et l'éclosion des oeufs.

5. On peut observer une succession des phénemènes où les oeufs

viables peuvent rester sans écolose quand l'habitat se desséche et pouvant survivre la desiccation, enfin pouvant arriver à maturité dans une période très courte.

6. Les effets probables de la congélation de l'habitat sont discutés.

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Notes on the Diatomaceae of Ahmedabad and Its Environs

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(with 1 plate)

Synopsis

In this note the Diatoms from the Gujarat College compound are systematically described and some notes or remarks are given on their occurrence, ecology and distribution in the region of Ahmedabad.

Introduction

With the exception of two small notes by the author (1959, 1960) there exist no other accounts of the Diatomflora of Ahmedabad region. In order to further add to the knowledge of this flora, the present paper is intended.

While collecting the diatom material from the region of Ahmedabad it was the upper most idea with the author that localities or habitats be classified or categorised and the diatom communities be investigated separately of such bodies of water. Accordingly, the plan was adopted and the body or bodies of water were studied separately under the following heads: 1) Road-side and village ponds, small tanks or large pools much disturbed by biotic agencies, therefore, amply polluted; 2) Garden reservoirs: a. with continuously disturbed water, b. long standing polluted disturbed water and c. undisturbed water for a long time with aquatic Angiosperms; 3) wet soils under garden taps along with ephemeral shallow puddles formed during the rains; 4) large permanent bodies of water e.g. large tanks, zhils or lakes subject to full force of climatal, edaphic and biotic factors; 5) road-side pools, puddles and ditches more or less secluded or unfrequented by many biotic agencies but subject to climatal and

edaphic factors; and lastly 6. the pools and slowly flowing water-courses in the river bed. These were all the possible wet situations available in the region of Ahmedabad. Further, it was thought that the collections be made at suitable regular intervals for a year, two or more where- and whatever was possible and the floristic element be examined more carefully and separately from type or set of habitats. Again, the samples of water be taken at different times and chemically analysed and findings be correlated with the occurrence of different species of diatoms. However, in this direction little could be done due to several factors the chief among them being, vicious bosses of the departments, sparse facility characteristically available at several Govt. colleges, indifferent Govt. administration and attitude and the finance.

Despite of manifold difficulties, the author collected a large number of algal samples from the region of Ahmedabad with reference to habitats mentioned above. From some of these, collections were drawn at suitable regular intervals, the material was studied and separate accounts were and are planned to ultimately present a sum-total picture of the diatom flora, elucidating features of interest, if any are found. Wheresoever it was possible, results of chemical analysis of water were availed and indicated with particular reference to salinity and pH.

In compliance with the aspired plan indicated above, studies have been published relating to habitats no. 1 and 2a. In this paper the diatom communities derived from habitats nos. 2b and 3 are dealt with. The material here was collected from the compound of the Gujarat College at a monthly interval from July 1956 to December 1957, this includes two rainy seasons. After this period the collection work got suspended on account of the author's transfer to a new place.

The material from garden reservoirs comprised of loose, granular, greenish, slimy masses of matter mixed with some species of Myxophyta, was collected in form of encrustations on inner walls of reservoirs and freely floating flakes of matter mostly derived from the same. This material represented only small forms of diatoms, among these *Amphiprora paludosa* W. SMITH v. *subsalina* CL., was predominant and was associated with *Caloneis beccariana* GRUN., *Nitzschia microcephala* GRUN. v. *elegantula* GRUN. and *Surirella ovalis* BRÉB. v. *guttata* Å. BERG, which also occurred in good numbers.

The wet soil samples and others derived from ephemeral rain-water puddles mostly showed the preponderance of species of *Nitzschia*, *Nitzschia amphibia* GRUN., *N.* - v. *acutiuscula* GRUN., *N. microcephala* GRUN. and *N. frustulum* (KÜTZ.) GRUN. being more common and often associated with species of *Achnanthes*, whereas other forms were recorded as stray specimens.

The salient feature of this study is that with the exception of *Navicula cuspidata* KÜTZ. v. *ambigua* (EHR.) CL., none of the diatoms showed more than 50 μ size. Even in case of the said diatom there were only very stray specimens noted of more than 50 μ length. In other words, the diatomflora was comprised of nannophytes and *N. cuspidata* v. *ambigua*, which was usually represented by much larger specimens (above 60 μ) elsewhere in Ahmedabad, was found here in conformity with the smaller life-forms by displaying nannism. Nothing could be done, due to several difficulties which confronted the author, to find out the causative factors or forces which prevented the formation of larger species of diatoms in these habitats. However, a fact could be recalled that in reservoirs there was ample contamination of rotting blackish green organic matter accumulated over years, high per centage of calcium carbonate and competing Myxophytes, besides water being disturbed fairly frequently. Whereas, in cases of samples derived from wet soils under garden taps and shortwhile rain-water puddles the soil factors must have been responsible as being pointed out by BRISTOL (1920), LUND (1945—46) and others, to promote the formation of small species of diatoms only. All the diatoms recorded from this locality were perennials with the exception of forms obtained from shallow ephemeral rain-water puddles. In the latter case, because of the collection work being discontinued with drying up of the soil. The frequency counts suggested only slight seasonal variations. Similar observations also were made of collections made from an identical garden reservoir at the M. N. College, Visnagar, during the year 1958 January to June 1959 when the author was attached to that college.

The source of water supply to the garden reservoirs happen to be a large garden well of which the data of water analysis is as follows for the year 1956—57:

Salinity (NaCl)		42—44 parts/100,000.
pH		7.8—8.2
Hardness	Temporary	21—24
	Permanent	nil.
Calcium sulphate		nil.

Taste somewhat saltish.

This data was obtained through the kind office of the Asstt. Officer-in-Charge Public Health Laboratory, Municipal Corporation, Ahmedabad, to whom the author's thanks are due.

In this account the dimensions are given for all the species of diatoms recorded from this area but as usual descriptions and illustrations are avoided of all those recorded elsewhere in the Indian literature with a few exceptions. Under each diatom short notes also

are given pertaining to their ecology, occurrence and distribution in the region of Ahmedabad. In case of *Caloneis beccariana* GRUN. and *Amphiprora paludosa* W. SM. v. *subsalina* CL , some life-history features also are brought into relief which conform to statements presented by HUSTEDT (1949—50) and CLEVE (1894—1895), respectively. The standard authentic works have been relied upon for the Halobion data.

SYSTEMATIC ENUMERATION

1. *Cyclotella meneghiana* KÜTZ. Diam. 10—17 μ and striae 7—8 in 10 μ.

This is a widely distributed species in whole of Ahmedabad but its gregarious formation was noted mainly in brackish waters (collections from Khari-cut canal). At other places it occurred in decaying masses of vegetable matter. In the present area it was recorded in good numbers in the encrustations but known to be stray in wet soil samples. Its place in the Halobion system .... Halophilous.

2. *Achnanthes microcephala* KÜTZ. Length 14—18 μ, breadth 2.8—3 μ and striae 28—30 in 10 μ.

This is also a widely distributed diatom in Ahmedabad. In certain reservoirs and road-side pools it was somewhat gregarious. However, in the present area it was fairly represented on the wet soils but was stray in reservoirs. Its place in the halobion system.............. Halophobous.

3. *Achnanthes pseudobiasolletiana* sp. nov. (Figs. 1—5)

Valvae 8—14 μ longae atque 2.8—3.5 μ latae, late-lanceolatae, apicibus constrictis, productis ac late-rotundatis. Valva raphida: raphe tenuis et recta; area axialis angustissima; area centralis parva ac paululum elliptica; striae circiter 28 in 10 μ, tenues atque aliquamtum radiales. Valva sine raphide: pseudoraphe angusta, linearis; area centralis indistincta; striae circiter 26—27 in 10 μ, aliquamtum radiales Typus lectus a H. P. GANDHI ad cisterna in horto die 1956—57, et positus in herbario proprio auctoris sub numero, slide AHM-GC. 5.

Valves 8—14 μ long and 2.8—3.5 μ broad, broadly lanceolate with constricted, produced broadly rounded ends. Valve with raphe: raphe thin and straight; axial area very narrow; central area small and very slightly elliptical; striae about 28 in 10 μ, fine and slightly radial. Valve without raphe: pseudoraphe narrow, linear; central area inevident; striae about 26—27 in 10 μ slightly, radial.

This diatom although looks like *A. biasolletiana* (KÜTZ.) GRUN. (VAN HEURCK 1896, *Treat. Diat.*, 281, pl. 8, f. 331; HUSTEDT, 1930, *Bacil.*, p. 199, f. 289; - 1930—37, *Kieselalg.*, p. 379, f. 823; CLEVE-EULER, A., 1951—55. *Diat. Schwed. Finn.*—III, 42, f. 573 a—e), in the shape but differs in being much more slender i.e. breadth being 2.8—3.5 only in contrast to the minimum of 4 μ, recorded for the smallest form by HUSTEDT and others. Moreover, the striae are slightly more in number besides they being distinctly radial on both the valves. It also differs from *A. wolffii* FOGED (FOGED, N., 1957, *Diat. Rennell Isl.*, p. 55, pl. 4, f. 16—17), in the similar details. It is hence considered to be a new species.

This species was collected from a couple of reservoirs growing in the encrustations and slimy depositions on dead floating leaves. It occurred in good numbers throughout the year. In the samples collected from the wet soils under the garden taps it occurred as a stray form. Elsewhere in the region of Ahmedabad it found no distribution except in some pools in the Sabermati river or similar garden reservoirs. Its place in the halobion system...............?

4. *Achnanthes affinis* GRUN.: Length 15—17 μ, breadth 3 μ, striae on raphe valve 28 and raphe-less valve nearly 30 in 10 μ.

This species was found to be well distributed in Ahmedabad but it usually occurred in small numbers mixed with vegetable matter and slime. It also occurred on wet soils, pools, puddles and ditches formed during the rains. In the present locality, it was mostly collected from rain-water puddles and wet soils under the garden taps. However, it was significantly absent from the reservoirs? Its place in the halobion system.................. Indifferent.

5. *Achnanthes exigua* GRUN.: Length 12—14 μ, breadth 4.2—4.5 μ and striae 25 on the raphe valve and about 22 on rapheless valve in 10 μ.

This diatom was collected from a variety of wet situations in Ahmedabad, but more abundantly noted from fountain reservoirs, road-side ponds, pools and large ditches and from the clusters of living and dead vegetable matter collected on borders of large tanks and lakes. In the present area it was quite frequently collected from wet soils under garden taps and rain-water puddles but in the reservoir it occurred only sparsely. Its place in the halobion system .... Indifferent.

6. *Caloneis beccariana* (GRUN.) CL. (Figs. 6—10)

CLEVE, P. T., 1894—95, *Synop. Nav. Diat.* pt. I, p. 50, pt. II, pl. 1, f. 7; HUSTEDT, 1949—1950, *Diat. Sinai-Halbinsel*, p. 44, f. 1—7; FOGED, N., 1959, *Diat. Afghanistan*, 49, pl. 7, f. 6; GANDHI,

1955, *Diat. Partabgarh*, p. 313, f. 11 (= *C. clevei* (LAGST.) CL.).

Valves 26—43 μ long and 5.6—8.2 μ broad, lanceolate to linear-lanceolate, somewhat inflated in the middle with constricted, capitate to subcapitate broadly rounded ends. Raphe thin or coarse and conspicuous with unilaterally bent central pores and slightly curved terminal fissures. Axial area fairly wide, linear-lanceolate to lanceolate, rarely narrower; central area quite large and reaching the sides, sometimes more widened on one side than the other or narrowly reaching the sides, otherwise quite variable. Striae 21—22 in 10 μ, but rarely upto 24 in 10 μ, particularly in some smaller forms, conspicuously radial, rarely less so in the middle but clearly convergent at the ends, crossed by a fine marginal line. The typical dimensions recorded for the type are as follows:

Length	Breadth	Striae in 10 μ
26 μ	6 μ	22
34.5 μ	7.6 μ	23—24
35 μ	7.5 μ	21—22
35 μ	7.6 μ	22
37 μ	7.5 μ	21—22
38 μ	8.2 μ	21—22
43 μ	7.5—8 μ	21—22

This diatom appears to be a very variable species both in the shape and structural details. With reference to the literature cited above, the shape varies from broadly lanceolate (CLEVE, HUSTEDT) to linear-lanceolate (HUSTEDT, FOGED) with ends distinctly capitate to subcapitate (HUSTEDT, FOGED) even apparently only broadly produced and rounded (HUSTEDT, f. 6) Looking at the axial area, CLEVE represents it to be uniformly narrow and linear, according to HUSTEDT it is narrowly lanceolate to broadly lanceolate as much as 1/3 or more the width of the valve (much differently indicated than by CLEVE) and FOGED indicates it to be extremely narrow Again, the central area seems to differ to a very large measure, from being very wide to narrowly reaching the sides, more widened on one side than the other (HUSTEDT), unilateral or not at all extended to the sides but only slightly formed (FOGED). The number of striae according to HUSTEDT and CLEVE are 21 in 10 μ but FOGED counts them to be 21—22 in 10 μ.

From the continuous examination of the material for over a period of a year all the variations indicated above were observed of which the present set of illustrations bear the testimony. However, the specimens illustrated by FOGED and HUSTEDT (cf. f. 4) were never observed.

Also the maximal dimensions were never recorded which are: 27—70 x 8—14 μ and 26—75 x 7 μ, according to HUSTEDT and CLEVE respectively. The number of striae usually recorded were 21—22 but rarely counted upto 24 in 10 μ, slightly closer towards the apices.

Again, from the present study it was felt that *C. hultenii* B. PETERSEN and *C. clevei* (LAGST.) CL. described by HUSTEDT (HUSTEDT, 1930, *Bacil.*, p. 236, f. 359) probably lie within the cycle of *C. beccariana* (GRUN.) CL. than the otherwise—but as boundry cases or remotely. Author's *C. Clevei* (GANDHI, 1955, *Diat. Partabgarh*, p. 313, f. 11) is also *C. beccariana*, as it could be ascertained with the availability of more and appropriate literature. Here, the author is grateful to Dr. B. J. CHOLNOKY for indirectly making a reference to this in one of his personal letters. VENKATARAMAN'S diagnosis of *C. clevei* (VENKATARAMAN, 1956, *S. I. Diat.*, p. 5, f. 10) appears to be unreliable in as much as that he gives in the text and illustration the course of striae to be radial throughout. He is, therefore, unreasonable in bringing reference of *C. hultenii* B. PET. While going through his paper under reference there may be found ample drawbacks which suggest that he bestowed little care in studying his material and the literature.

Further, from the continuous observations of the collection it was also felt that HUSTEDT's fig. 6 of *C. beccariana* be treated as a variety, since these smaller forms here not only showed broadly produced rounded ends but also somewhat denser striae, about 26—27 in 10 μ, which is being effected in the following.

This species was collected from the garden reservoirs in abundance growing among other things in the slimy encrustations. Its period of maximum growth was in months of September and October 1956/57, but for the rest of the year it was seen in lesser numbers. This species does not seem to be well distributed in Ahmedabad since only 10% of samples were found to contain it usually in smaller number. These collections were from similar habitats. A couple of tubes from the Kankaria lake also represented it as a stray form. Its place in the halobion system..................................?

7. *Caloneis beccariana* v. *hustedtii* v. nov. (Figs. 11—12)

Valvae 13.2—22 μ longae atque 5—5.2 μ latae lineari-ellipticae vel subellipticae, apicibus constrictis, late-productis et rotundatis. Raphe tenuis et recta, poris centralibus aliquantum unilateraliter inclinatis atque fissuris terminalibus aliquantum curvatis. Area axialis angusta, sublanceolata; area centralis angusta, rectangularia ad margines perveniens. Striae circiter 26—27 in 10 μ, paulum radiales atque in utroque apice paululum convergentes et lineam

longitudinalibus ad margine interruptae. Typus lectus a H. P. GANDHI ad cisterna in horto die 1956—57, et positus in herbario proprio auctoris sub numero, slide AHM—GC. 6.

Valves 13.2—22 μ long and 5—5.2 μ broad, linear-elliptical to subelliptical with constricted, broadly produced rounded ends. Raphe thin and straight with central pores unilaterally bent and terminal fissures slightly curved. Axial area narrowly lanceolate; central area small, rectangular and reaching the sides. Striae about 26—27 in 10 μ, slightly radial and towards the apices very slightly convergent, crossed by the longitudinal line near the margines.

This diatom differs from the above type in having clearly constricted broadly produced rounded ends. Moreover, the central area is small, rectangular and the striae are comparatively denser. It is therefore regarded as a new variety and named in honour of Dr. HUSTEDT of Bremen.

This diatom was found associated with *C. beccariana* (GRUN.) CL. in encrustations of reservoirs. It occurred usually in small number throught the period of investigation, but never seen from the wet soils. From other parts of Ahmedabad, it was sparingly seen but a couple of samples got from fountain reservoirs of Seth Sarabhai's garden contained it in small a number. Its place in the halobion system.........................?

8. *Caloneis bacillum* (GRUN.) MERESCH. (Fig. 13): Length 14.2—18 μ, breadth 5.6—6 μ and striae 26—28 in 10 μ.

This species was collected principally from garden reservoirs, fountains, in some road-side pools, Chandola and Kankaria lakes, usually mixed with living and dead vegetable matter. It was found to be fairly distributed in the region of Ahmedabad. In the present area it occurred in the reservoirs as well as on the wet soils under the garden taps. Stray specimens also were seen in rain-water puddles of longer duration. It appeared conspicuously in reservoirs during October and lasted thus till middle of November then it was stray. Its place in the halobion system .... Indifferent.

9. *Navicula cuspidata* KÜTZ. v. *ambigua* (EHR.) CL. (Fig. 14) Length 38.2—69 μ, breadth 10.5—16 μ, transverse striae about 18 and longitudinal ones about 27 in 10 μ, longitudinal striae were found to be rather indistinct.

This diatom finds a very wide distribution in the region of Ahmedabad but was never known to occur in abundance. It was also obtained from moist soils occassionally with craticular plates. In the present area it occurred usually in smaller numbers both in the

garden reservoirs and wet soils for the entire period of investigation. From the reservoirs very small specimens were collected of which probably no record exists in the literature. Its place in the Halobion system .... Indifferent.

10. *Navicula mutica* Kütz. Length 12—18 μ, breadth 7—7.4 μ, striae about 18 in 10 μ.

This diatom was collected mostly from wet soils under the garden taps and rain-water puddles associated with different species of *Nitzschia*. In encrustations of reservoirs it was singularly absent. Elsewhere in Ahmedabad, it occurred usually in similar situations as also in the marginal slime of ponds, tanks and road-side pools. Stray specimens also were collected from Naginawadi pool around a leaking pipe. Its place in the Halobion system ...... Indifferent.

11. *Pinnularia macra* sp. nov. (Figs. 15—16)

Valvae 14—23 μ longae atque 3—3.6 μ latae, parvae, lineares, marginibus parallelis vel leniter convexa, apicibus valde constrictis, late capitatis rotundatis. Raphe tenuis et recta, ornata poris centralibus unilateraliter inclinatis, fissuris terminalibus curvatis. Area axialis plus minus late-lanceolata; area centralis amplissima, rhomboidea usque ad margines perveniens. Striae 16—18 in 10 μ, crassae, radiales ac gradatim abbreviatae in medio atque in utroque apice convergentes. Typus lectus a H. P. Gandhi ad solum humidus in horto die 1956—57, et positus in herbario proprio auctoris sub numero, slide AHM—GC. 8.

Valves 14—23 μ long and 3—3.6 μ broad, small, linear, sides parallel to feebly convex, ends strongly constricted, broadly capitate and rounded. Raphe thin and straight with central pores unilaterally inclined and terminal fissures curved. Axial area more or less broadly lanceolate; central area quite large, rhomboid and extended to the sides. Striae 16—18 in 10 μ, coarse, radial and gradually abbreviated in the middle and convergent at the ends. The following is the table of typical dimensions recorded for this type

Length	Breadth	Striae in 10 μ
14 μ	3.3 μ	16
15.3 μ	3.1 μ	16
16 μ	3.3 μ	17—18
23 μ	3.0 μ	16—18
23 μ	3.6 μ	18

This species does not compare well with any of the following species

1. *Pinnularia interrupta* W. SM. f. *minor* B. PET. (PETERSEN, 1928, *Aërial Alg. Iceland*, p. 405, f. 25) = *P. biceps* GREG. v. *minor* (B. PET.) A. CL. (CLEVE-EULER, 1955, *Diat. Schwed. Finn.* -IV, p. 63, f. 1088 k—n).
2. *P. interrupta* f. *minutissima* HUST. (HUSTEDT, 1930, *Bacil.*, p. 317, f. 574) = *P. biceps* v. *gregorii* A. CL. f. *minutissima* HUST. (CLEVE-EULER, *op. cit.*, p. 62, f. 1088 g).
3. *P. kneuckerii* HUST. (HUSTEDT, 1949—50, *Diat. Sinai Halbinsel*, p. 50, f. 22—32; FOGED, N., 1959, *Diat. Afghanistan*, 65, pl. 8, f. 4—5).
4. *P. saxicola* J. W. G. LUND (LUND, J. W. G., 1946, *Soil Alg.*-II, p. 88, f. 10 G—I; FOGED, N., *op. cit.*, p. 65, pl. 8, f. 6)

and some others, although all these have smaller size and more or less a similar appearance. The present species, however, is distinguished from the rest in having much slender valves (the maximum breadth of which is only 3.6 μ in contrast to others), very clearly capitate rounded ends, wide lanceolate axial area, enlarged rhomboid central area (also present in *P. saxicola*) and more important is the course of striae which are clearly radial and gradually abbreviated in the middle part unlike in *P. saxicola* which is also a soil diatom. Again, this species has some resemblance of *P. interrupta* f. *minutissima* HUST. of FOGED (FOGED, N., 1957, *Diat. Rennell Isl.*, p. 72, pl. 7, f. 10) but the author remarks that „. . . . . has been referred here with some hesitation", after referring to HUSTEDT's type. Considering these remarks to be valuable, it is felt here to erect present specimens as a new species.

This species was fairly well represented in the collections from the college compound. It occurred more frequently in encrustations of reservoirs along with *Caloneis beccariana* (GRUN.) CL. and *Amphiprora paludosa* W. SM. v. *subsalina* CL. as well as in granular mass floating on the water surface. Some samples derived from wet soils under the garden taps also yielded it in smaller numbers. From other parts of Ahmedabad, it was only casually recorded and that too from similar situations. This species became more frequent in the reservoirs during late October. Its place in the Halobion system . . . .?

12. *Amphiprora paludosa* W. SM. v. *subsalina* CL. (Figs. 17—19) CLEVE, P. T., 1894—95, *Synop. Nav. Diat.*,—I, p. 14; HUSTEDT, 1930, *Bacil.*, p. 340; CLEVE-EULER, A., 1952, *Diat. Schwed. Finn.*—V, 31, f. 1400 m.

Frustules 25.6—50 μ long and 26—27/28—32 μ broad at the broadest and at constriction 19—22 μ broad, very weakly silicified

hence delicate, somewhat obliquely or sigmoidly rectangular, deeply constricted in the middle with broadly rounded corners in the girdle view. Alae strongly undulate with deep rectangular but irregular recesses 1—2 (of junction line). Longitudinal bands in girdle zone fine, numerous, 12—15 in 10 μ, slightly sigmoid. Striae 18—20 in 10 μ, usually 22—24 in 10 μ, fine but distinct and radial.

This diatom was found to be abundantly growing in mucilagenous matter encrusting the reservoirs or in free-floating masses detached from the same. In fresh-condition it appeared conspicuously with olive-green or pale chromatophores. It became more abundant during late September both in the reservoir and in a large tumbler kept under observation since August 1957, in a secluded corner of the laboratory. From the observations it appeared to be a very variable type corroborating the statement of CLEVE, „*A. paludosa* is a very variable species, closely connected with *A. alata* KÜTZ. . . .” Some of the specimens illustrated here perhaps bear the testimony to the same. From other parts of Ahmedabad, it has not been observed, perhaps it may be due to its very hyaline nature hence passed unnoticed. Its place in the Halobion system . . . . Mesohalobous

13 *Amphora veneta* (KÜTZ.): Length 14—20 μ, breadth 7—10 μ, striae 20—26 in 10 μ

This diatom was mostly collected from wet soils under garden taps, on the border of ponds, pools, tanks and other similar situations. Stray specimens also were collected from the garden reservoirs occurring in encrustations. A fairly well distributed diatom in Ahmedabad. Its place in the Halobion system . . . . Indifferent

14 *Amphora acutiuscula* KÜTZ. (Figs 20—21)

CLEVE, P. T., 1895, *Synop. Nav. Diat.*, pt. II, p. 121; CLEVE-EULER, A., 1953, *Diat. Schwed. Finn.*—III, p. 98, f. 686 a—b; HUSTEDT, 1930, *Bacil.*, p. 346 (= *A. coffaeaformis* AG. v. *acutiuscula* (KÜTZ.) HUST.).

Frustules 21—27 μ long and 9—11 μ broad, linear-elliptical with constricted, broadly produced, truncate ends in girdle view. Longitudinal bands in the girdle view many and fine. Valve convex and somewhat straight in the middle part on the dorsal side and slightly concave on the ventral side; ends produced and narrowly capitate. Raphe thin, straight and close to the ventral side. Central area not clearly defined. Striae 16—18 in 10 μ, radial and interrupted by longitudinal hyaline bands.

This diatom was collected from many parts of Ahmedabad in smaller or larger numbers. It was found sparingly in road-side pools, ditches and ponds, but more frequently in garden reservoirs and

fountains. In the present area it occurred in encrustations of reserviors as well as on moist soils under garden taps and rain-water puddles, but in the latter case only as a stray specimen.
Its place in the Halobion system .... Mesohalobous.

15. *Hantzschia amphioxys* (Ehr.) Grun. Length 22—38 μ, breadth 5—6 rarely 7 μ, keel punctae 6—8 in 10 μ, striae 16—20 in 10 μ.

This diatom was collected mostly from rain-water pools, puddles or ditches mixed with fine slime and/or clusters of wet mosses on the garden brick-work. In the present area it was found in samples derived from wet soils under garden taps and rainwater puddles. A widely distributed diatom but occurring only in small numbers with the exception of some rainwater puddles. Its place in the Halobion system .... Indifferent.

16. *Nitzschia microcephala* Grun. Length 8—14 μ, breadth 2.8—3 μ, keel punctae about 13 in 10 μ, striae 30—32 in 10 μ.

This is a widely distributed species in Ahmedabad, frequently found in pools, ponds, ditches specially in the marginal slime. In the present area it occurred in encrustations of reservoirs as well as on wet soils under garden taps and rain-water puddles. Its place in the Halobion system .... Halophilous or Indifferent.

17. *Nitzschia microcephala* v. *elegantula* Grun. (Fig. 22)

Van Heurck, 1896, *Treat. Diat.*, p. 402, pl. 17, f. 559; Cleve-Euler, A., 1952, *Diat. Schwed. Finn.*—V, p. 88, f. 1499 e.

Valves 9.5—13 μ long and 2.5—2.8 μ broad, small, linear with slightly concave sides in the middle and constricted, distinctly produced capitate ends. Keel very excentric with small but distinct keel punctae 12—13 in 10 μ. Striae about 26—30 in 10 μ, rather fine.

This diatom appears like *N. jugiformis* Hust. (Hustedt, 1922, *Bacil. Innerasien*, p. 149, pl. 10, f. 60—61) but differs in not having deeply constricted middle part. Moreover, the apices here are more abruptly narrowed therefore broadly cuneate, constricted produced and capitate. Keel punctae also are somewhat denser. Here the author wishes to express his grateful thanks to Dr. P. J. Halicki for supplying the photostat copy of this much needed reference.

This species was well represented in the region of Ahmedabad. It was collected from several garden reservoirs, fountains, storage tanks and on permanently wet soils under garden taps. It mostly occurred in association of some Myxophyta but sometimes also in slimy films on wet soils. In the present locality, it was available everywhere but more in number in encrustations of reservoirs. Its period of maximum growth was noted to be from November to December. Its place in the Halobion system ....?

18. *Nitzschiaa mphibia* GRUN. (fig. 23) Length 13—35 μ, breadth 3—4 μ, keel punctae 8—9 in 10 μ, striae about 17—18 in 10 μ.

19. *Nitzschia amphibia* v. *acutiuscula* GRUN. Length 20—42.6 μ, breadth 3—5 μ, keel punctae 7—8 in 10 μ and striae 16 in 10 μ.

These two diatoms were found throughout the region of Ahmedabad, mostly occurring in the slimy matter lying on borders of wet situations. In samples derived from wet soils they were usually smaller in size. In certain ponds they were gregarious. In the present locality, they occurred both in the garden reservoirs and wet soils under taps and puddles. Their place in the Halobion system .... Indifferent.

20. *Nitzschia frustulum* (KÜTZ.) GRUN.: Length 20—30 μ, breadth 3—4 μ, keel punctae 9—11 in 10 μ, striae about 22 in 10 μ

This species was collected along with the above type but sometimes more commonly seen in certain pools, puddles and ditches on the road-side. In the present area it occurred mostly on wet soils, rain-water puddles and pools but only stray specimens were seen in samples from garden reservoirs. Its place in the Halobion system ... . Indifferent.

21. *Nitzschia lancettula* O. MÜLL. (Fig. 24)

SCHMIDT, A., 1874—1944, *Atlas Diat.*, t. 348, f. 52—53; HUSTEDT, 1949, *Diat. Albert Nat. Park*, p. 141, t. 13, f. 39—47.

Valves 15—18 μ long and 4.7—5.5 μ broad, broadly lanceolate with narrowed produced rounded ends. Keel very excentric with keel punctae 7—8 in 10 μ, small beaded and distinct. Striae 16—18 in 10 μ, fine but distinctly punctate, punctae about 18—20 in 10 μ.

This diatom occurred comparatively in smaller number of collections from Ahmedabad. Most of these collections were from garden reservoirs, fountains or some permanently wet soils. With the exception of 3—4 samples it was mostly recorded as a stray biotope. In the present locality it was found more abundantly in reservoirs than on wet soils. Its place in the Halobion system .... ? Indifferent.

22. *Nitzschia torta* sp. nov. (Figs. 25—26)

Valvae 36—40 μ longae atque 3.3—3.8 μ latae, lineares, aliquantum arcuatae, apicibus constrictis, longe-cuneatis rostratis et rotundatis. Carina valde excentrica, punctis carinalibus 7—8 in 10 μ, crassis atque distinctis, mediis duobus remotioribus. Striae 18 vel 20 in 10 μ, distincte punctatae. Typus lectus a H. P. GANDHI ad cisterna in horto die 1956—57, et positus in herbario proprio auctoris sub numero, slide AHM—GC. 19.

Valves 36—40 μ long and 3.3—3.8 μ broad, linear, slightly arcuate with ends constricted, long-cuneate, rostrate and rounded. Keel strongly excentric, keel punctae 7—8 in 10 μ, coarse and distinct, two of the middle one distantly set. Striae 18 to 20 in 10 μ, distinctly punctate.

This species does not agree with any of the known types hence it is considered to be a new species. The figure no. 26 depicts an anomalous form found with the type.

This diatom was represented only in a small number of collections from Ahmedabad. These collections were mostly made from garden reservoirs and fountains by scraping the encrustation. In all these samples it appeared as a stray diatom. From the present area it was well represented in the garden reservoirs as a delicate yet beautiful *Hantzschia* like form. Its place in the Halobion system ....?

23. *Surirella ovalis* (Bréb.) v. *guttata* Å. Berg (Figs. 27—28)

Berg, Å., 1945, *Diat. Sophia-Expedition*, p. 23, t. 8, f. 281. Valves 33.8—43.7 μ long and 22.6—26.6 μ broad, heteropolar, broadly ovate with rounded apex and comparatively narrower base distinctly constricted, produced and rounded. Axial area a very narrow pseudoraphe. Flap margin not developed, flap projections and windows absent. Costae 30—45 in 100 μ, rib-like, not reaching the middle-line, radial but more so towards the ends, alternating with 3—5 clear striae. Striae about 18—19 in 10 μ, coarse and strongly radial towards the ends. In certain specimens striae seemed to show a longitudinal refractive band which appeared to shift with the change of focus.

This species was represented in a small number (about 25 specimens in all were counted) in encrustations of reservoirs associated with *Caloneis beccariana* (Grun.) Cl. and *Amphiprora paludosa* W. Sm. v. *subsalina* Cl. Elsewhere in Ahmedabad it was not observed except in a few samples brought from fountain reservoirs of Seth Sarabhai's garden. In the latter case it was found associated with *S. ovalis* Bréb. and some *Dianoflagellates*. Its place in the Halobion system .... ?

In light of the existing Halobion data of these diatoms, the following Halobion spectrum could be represented, thus

Mesohalobous species		2	which make	8.7 %	app.
Oligohalobous...	Halophilous	2	,, ,,	8.7 %	,,
	Indifferent	11	,, ,,	47.826%	,,
	Halophobous	1	,, ,,	4.348%	,,
?...... i.e. undetermined species		7	,, ,,	30.434%	,,
				- 0.008%	,,
	Total	23		100.000	

Likewise, the pH-spectrum from the available records is the following:

Acidophilous	0	which make	00.00 %	app.
Indifferent	2	,, ,,	8.70 %	,,
Alkaliphilous	12	,, ,,	52.174%	,,
?.. i.e. undetermined species	9	,, ,,	39.130%	,,
			- 00.004	
Total	23		100.000	

From the above Halobion spectrum it appears that a large number of salt loving diatoms exist in the present locality, especially in the garden reservoirs which means that the water is somewhat brackish. This fact seems to be corroborating with the results of chemical analysis of water available where the average range of salinity found to vary from 42 to 44 parts per 100,000. With regards to the pH the water is markedly alkaline and therefore the Diatomflora is largely alkaliphilous with the exception of *Achnanthes microcephala* KÜTZ. and *Navicula mutica* KÜTZ. which are indifferent according to FOGED (1959). The remaining nine undetermined species with regard to pH may be considered as alkaliphilous on the basis of local data, until otherwise is proved.

Of the seven undetermined species of Diatoms of their Halobion character, the following consideration could be made:

Caloneis beccariana (GRUN.) CL., *C.* - v. *hustedtii* v. nov., *Achnanthes pseudobiasolletiana* sp. nov., *Pinnularia macra* sp. nov., *Nitzschia microcephala* GRUN. v. *elegantula* GRUN., and *Surirella ovalis* BRÉB. v. *guttata* Å. BERG, may be recognised at least as halophilous species, since they occurred in abundance to good numbers in the water more or less of saline tendency. In the literature, *Caloneis beccariana*, *Surirella ovalis* (Euryhaline to Mesohalobous) and *Nitzschia microcephala* v. *elegantula*, are reported only from the

brackish water and the last entity even from marine habitat. Again, *Caloneis beccariana*, was collected from highly polluted pools at Partabgarh (GANDHI, 1955) in which it occurred in encrustations on wet or partially submerged rocks. Moreover, all the above named entities were found here in close association of dominant species *Amphiprora paludosa* W. SM. v. *subsalina* CL. which has a marked Mesohalobous character. These observations, therefore, substantiate the present supposition—and indicate also the character of water in reservoirs. The constant presence of these Diatoms in good numbers here contemplates again that they belong to at least Halophilous if not Mesohalobous category, they being governed by the same ecological conditions as *Amphiprora paludosa* v. *subsalina* CL.

Regarding the one remaining Diatom, *Nitzschia torta* sp. nov., nothing could be said since the present data is rather meagre.

In the light of above consideration the Halobion spectrum becomes modified, thus:

Mesohalobous species		2 which make	8.7 %	app.
Oligohalobous	Halophilous	8 „ „	34.782%	„
	Indifferent	11 „ „	47.826%	„
	Halophobous	1 „ „	4.348%	„
?.... i.e. undetermined species		1 „ „	4.348%	„
			- 0.004%	„
	Total	23	100.000	

Further, concerning the diatom periodicity in the garden reservoirs nothing better could be said than that practically all the recorded species were permanent dwellers, and the seasonal fluctuation was represented only by a very small number of them as indicated in the text.

SUMMARY

While summarizing the results of the present investigation, the following could be stated:

that with the exception of two small notes by the author there exists little information of the Diatomflora of Ahmedabad region.

The diatoms of the present area are a special kind of biotopes characterised by small size. However, the causes leading to this nannism remain to be determined.

The observations regarding *Caloneis beccariana* (GRUN.) CL. and *Amphiprora paludosa* W. SM. v. *subsalina* CL., found to be in close harmony with those of HUSTEDT and CLEVE, respectively and further it is confirmed that they are very variable species.

The water of the present locality could be called somewhat

brackish on the basis of a large number of salt-loving diatoms being found here. Moreover, they are all alkaliphilous even the new entities with the exception of two which are known to be indifferent for the pH.

In light of the existing Halobion data and local observations some of the new entities and a few others are assigned their Halobion status. The spectrum relating to the same is also given.

The distribution of these diatoms is indicated for the region of Ahmedabad.

With regard to their periodicity recorded for over a year it was observed that almost all the species were perennials and a few among them showed slight rises any time from September to December.

Lastly, in all twenty-three diatoms are recorded from the present area representing ten genera. Of these, six are new records for India and three species and one variety is considered to be new.

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N.B.: The following „ERRATA" appear to be necessary in *HYDROBIOLOGIA* Vol. XIV, no. 2, 15.12.1959, and the author is sorry that through oversight they remained so long.

Page	Line	For	Read
111	36	„cum lineis aeque distantibus"	parallelis
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133	27	„(Figs. 3—8, 18)"	(Figs. 3—8, 19)
135	23	„(Figs. 11—20, 20)"	(Figs. 11—12, 20)
136	1	„s,"	is,
138	35	„(Fig. 14)"	(Fig. 13)
139	19	„(Fig. 15)"	(Fig. 14)
	35	„(Fig. 16)"	(Fig. 15)
140	6	„(Fig. 17)"	(Fig. 16)
	19	„(Fig. 18)"	(Fig. 17)

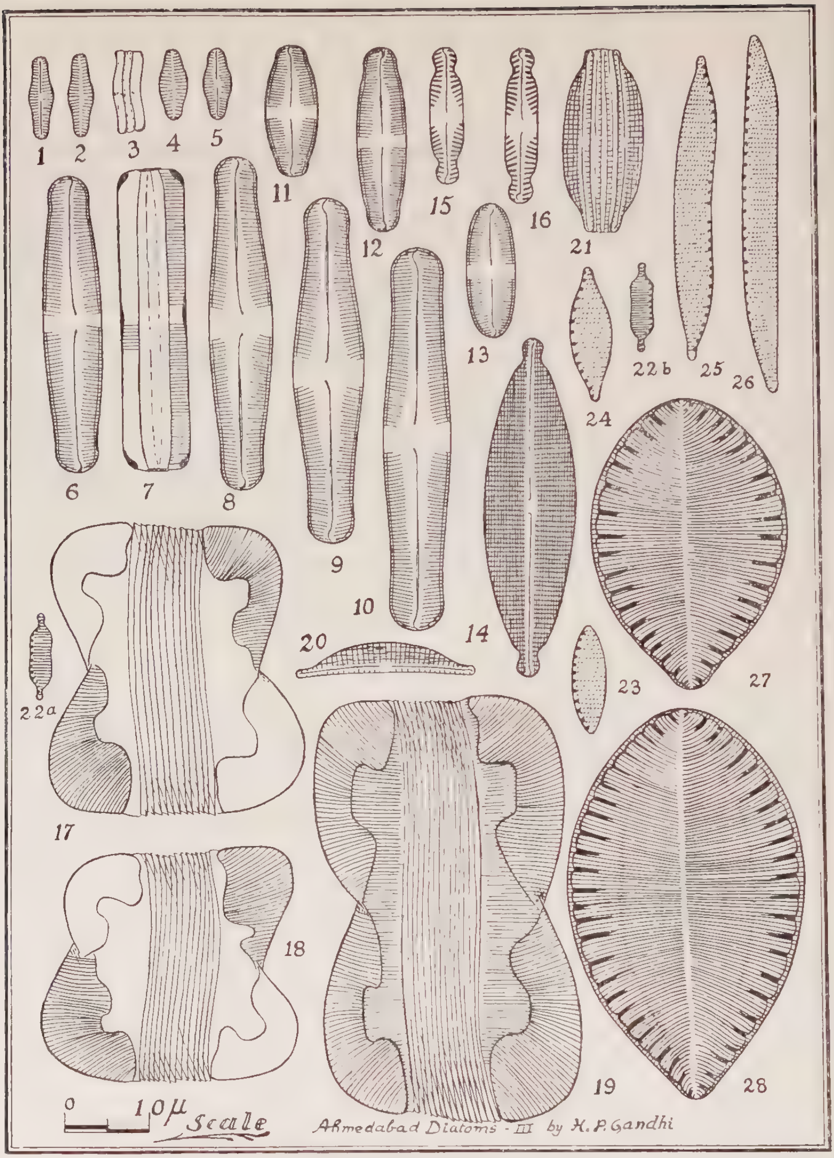

PLATE I

Fig. 1—5. *Achnanthes pseudobiasolletiana* sp. nov.
Fig. 6—10. *Caloneis beccariana* (GRUN.) CL.
Fig. 11—12. *C.* - v. *hustedtii* v. nov.
Fig. 13. *C. bacillum* (GRUN.) MERESCH.
Fig. 14. *Navicula cuspidata* KÜTZ. v. *ambigua* (EHR.) CL.
Fig. 15—16. *Pinnularia macra* sp. nov.
Fig. 17—19. *Amphiprora paludosa* W. SM. v. *subsalina* CL.
Fig. 20—21. *Amphora acutiuscula* KÜTZ.
Fig. 22. *Nitzschia microcephala* GRUN. v. *elegantula* GRUN.
Fig. 23. *N. amphibia* GRUN.
Fig. 24. *N. lancettula* O. MÜLL.
Fig. 25—26. *N. torta* sp. nov. (no. 26 is an anomalous specimen)
Fig. 27—28. *Surirella ovalis* BREB. v. *guttata* Å BERG

Studies on Chrysophyceae from Some Ponds and Lakes in Alaska. I.

Mallomonas Species Examined with the Electron Microscope

by

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(with 27 figs.)

INTRODUCTION

This paper is intended as the first one in a series of papers dealing with species of Chrysophyceae occurring in samples collected by DOUGLAS K. HILLIARD in some lakes and ponds in Alaska. It includes description and discussion of *Mallomonas* spp. by BERIT ASMUND and notes of topography, geology, vegetation, temperature, and chemistry on the waters at the time of sampling by DOUGLAS K. HILLIARD.

When not otherwise stated all figures are of electron micrographs and enlarged about 10650X.

DESCRIPTION OF LOCALITIES

The *Mallomonas* species reported on herein were collected from a variety of habitats extending from Kodiak Island (57° N.) to Cape Thompson (68° N.). An account of these is as follows.

I. Ponds near Anchorage.

During the period May, 1957 to May, 1958, plankton samples were gathered from surface waters of three small ponds situated 5 km south by south-west of Anchorage. Although sampling was done on nearly a weekly basis, only those collections representing fall and spring maxima of *Mallomonas* species and *Synura* species are considered here.

The unnamed ponds, designated as I, II, and IV, measure about 130 m by 130 m, 100 m by 200 m, and 200 m by 250 m, respectively; these are confined within a radius of 450 m. Mean depth for all is about 1.5 m, with a maximum depth of 2.5 m. The elevation above sea level is 10 m. Geologically, this region has been glaciated, with a resultant deposition of gravel, sand, silt, and clay; the latter is covered by a 20 cm layer of coarsely-fibered sedge and *Sphagnum*. Humus appears sparingly, since the surface horizons evolved during the Plistocene or later. The soil type, according to KELLOG & NYGARD (1951), is classified as ground-water podzols and is characterized by its extreme acidity (pH 3.5 at the Ao horizon).

The immergent vegetation for all ponds consists of *Nuphar polysepalum*, *Nymphaea alba*, *Sparganium* sp., and *Potamogeton natans*, while at the periphery *Myrica gale* and *Betula nana* abound. Climax vegetation at slightly higher elevations includes *Picea mariana* and *Betula paparifera*.

Water analyses at the time of sampling are given below.

	Date	pH	mg/l CO_2	mg/l Alk.	Cond. (x. 10^{-6})	mg/l Ca	mg/l PO_4	mg/l SiO_2	mg/l Fe	mg NO
Pond I,	XI-20-57	6.8	11.0	2.0	103.0	15.7	0	2.03	0	0
Pond I,	XII- 5-57	7.2	7.7	6.0	105.0	15.7	0	4.56	0	1
Pond II,	V-15-57	6.3	3.3	5.5	56.7	3.5	0.01	2.33	0	0
Pond II,	VI- 8-57	6.7	8.6	17.0	57.0	3.0	0	0.51	0	2
Pond IV,	XII- 5-57	6.4	8.8	7.0	95.4	15.0	0	17.80	0	1

Due to the close proximity and similarity in size, water and air temperatures were comparable; these are shown in the table below.

Year	1957					
Dates	V-15	VI-18	XI-20	XII-5	XII-10	XII-19
Air Temp.	14.4°	15.4°	0.56°	-12.5°	-18.6°	-16.2°
Water Temp.	12.2°	21.8°	8.6°	0.3°	0.3°	0.3°

From the standpoint of typology, these ponds doubtless belong to the physiologically oligotrophic type (DONAT, 1926), undergoing an alternately slightly acid- alkaline phase(Hampen Sø), according to IVERSEN, 1929.

The phytoplankton, whose periodicity, ecology, and systematics

will be treated by the authors in a subsequent publication, are given only cursoriol consideration here.

In the table below average values per liter are given representing a one year period.

	Pond I	Pond II	Pond IV
Desmidieae	19	23	11
Chlorophyceae (s. str.)	155	38	10
Euglenophyceae	2	5	8
Dinophyceae	98	35	114
Chrysophyceae	7660	186	2140
Bacillariophyceae	11	28	82
Myxophyceae	6	8	117

II. Karluk Lake, Kodiak Island.

Karluk Lake is situated in the southern portion of Kodiak Island, at 57° 24' N, 154° 5' W. The lake is 19.6 km long by 3.2 km at its maximum width; it has a surface area of 38.4 sq. km, a maximum depth of 123 m, and a mean depth of 48 m. The elevation above sea level is 107 m. Geologically, the lake basin is of recent glacial origin. The littoral area is composed essentially of a ledge of shale with poorly developed subaqueous terraces; these drop precipitously within a few meters of the shore.

Vascular aquatics are scarce in this lake, due, mostly, to a rocky substrate and precipitous shore line. *Potamogeton* spp. and *Vallisneria* sp. are sparingly represented in some littoral areas. *Chara* sp., however, are found to grow profusely to depths of 10 m in diatomaceous ooze.

Chemical analyses were not made at the time of sampling. However, a detailed account of the lake's chemistry is given in JUDAY *et al.* (1932), for the summer months over a four-year period. On the basis of these studies, it would appear that the surface waters are alkaline ranging from pH 7.2 to 8.6, with the water at lower levels neutral. Dissolved oxygen varied from 8.8 to 12 mg/l and approached with in 90 percent saturation. Both carbon dioxide and calcium demonstrated little change during this time, with values of 9—10 mg/l and 5—6 mg/l, respectively. Nitrate nitrogen fluctuated considerably (.012—.05 mg/l), while soluble phosphorus ranged from 0.002 mg/l at the surface to 0.02 mg/l at lower levels.

Temperatures at the time of sampling are indicated below.

Date	Water	Air
IX- 6-57	11.7°	14.4°
X-31-57	1.7°	-7.8°
IX-21-58	8.3°	6.7°

Regarding the classification of Karluk Lake, it may be stated without reservation that it is a classic example of an oligotrophic

lake. This is evidenced by its low quantity of electrolytes, uniformly high dissolved oxygen content, great mean depth, and poverty of aquatic plants. In employing the compound coefficient, recently advanced by NYGAARD (1949), a figure of 0.74 was arrived at; this represents 28 samples collected over a period of one year. This value falls well within the limits of NYGAARD'S definition of an oligotrophic lake.

Since the phytoplankton of Karluk Lake has been previously investigated by JUDAY *et al.* (op cit), CROASDALE (1958), and HILLIARD (1959), it will not be elaborated on here. In general, though, it was found that the percentage values for the total numbers of phytoplankters representing 46 collections were, in order of dominance, as follows: Desmidieae 84.8, Chlorococcales 12.4, Chrysophyceae 2.1, Dinophyceae 0.4, and Myxophyceae 0.2.

III. Inundate ground near Cape Thompson.

During July and August, 1959, a phycological survey was made near Cape Thompson, at 68° 6' N, 165° 45' W, where sampling was conducted from a variety of habitats. In these collections were several samples containing many interesting *Synura* species and *Synura*-like organisms, which have been included in the present consideration.

Species reported on herein were collected from temporary pools (ca. 1 m in diameter and 0.4 m deep) formed from melting snow in the spring and sustained by summer rains. These are situated on a bluff of hillocks facing the Chukchi Sea. The pools are mostly found in troughs between tussocks of *Eriophorum vaginatum* or in depressions resulting from adjacent frost ridges. Elevation above sea level of pools sampled was usually about 7 m.

Vegetation found in the vicinity of the pools consisted of *Sphagnum* spp. near the margins, and of *Salix pulchra*, *Polygonum viviparum*, *Dryas octopetala*, and *Lupinus arcticus* in the drier areas.

A chemical examination of one of the pools is shown below (in mg/l).

PO_4	Ca	Mg	Cl	Fe	SiO_4	Sp. Cond. (x. 10^{-4})	NO_4	pH
0	0	0	1.2	0.3	0.07	14.2	0.23	5.4

At the time of sampling the water temperature was 10°. Due to a prevailing cold wind from the east, low temperatures persist throughout the summer months.

An examination of the phytoplankton from the pools showed the following percentage of composition. Desmidieae 69.5 %, Myxophyceae 20.7 %, Chrysophyceae 7.3 %, Chlorococcales 1.2 %, and Euglenineae 1.2 %.

IV. Lake Louise and Lake Susitna.

Fair numbers of *Mallomonas* species were observed from two adjoining lakes on IX-19-59. The lakes, Louise and Susitna, are oriented in a north-south direction and measure 16.2 km by 11.4 km and 17 km by 4.8 km, respectively. These are joined by a narrow channel, at 62° 23' N, 146° 21' W. The elevation above sea level for these is about 722 m. Preliminary soundings showed the main channel of both lakes to have depths greater than 35 m. Vegetation surrounding the lakes consists mostly of *Picea mariana* and *Sphagnum* tussocks. A chemical examination of the water was not made, although pH for both lakes was about 7.1. The water temperature of Louise and Susitna at the time of sampling was 12° and 13°, respectively. An examination of the phytoplankton showed the following percentage of composition.

	Lake Louise	Lake Susitna
Bacillariophyceae	47.0	9.0
Desmidieae	3.7	1.0
Myxophyceae	29.4	2.5
Chrysophyceae	5.9	83.5
Dinophyceae	2.2	3.0
Chlorococcales	11.8	1.0

Description of the Mallomonas Species

The genus *Mallomonas* belongs to the Chrysophyceae. The *Mallomonas* species are free-swimming, fresh-water organisms covered with silica scales that form a flexible armour. The scales may bear movable bristles or immovable spines. Structure of scales and number and structure of bristles are important taxonomical features. Each scale consists of a delicate plate perforated by minute holes, more or less regularly spaced. On the plate foldings, ridges, papillae, etc. are deposited. A certain group of species has tripartite scales consisting of dome, shield, and flange and bearing a V-shaped ridge; the bristles are fastened to the dome. Fig. 1 shows what is meant by these designations. A more detailed description of tripartite scales is given by Harris (1953, pp. 95—97), Harris & Bradley (1957, pp. 38—39, 41), and Asmund (1959, pp. 9—10).

The *Mallomonas* species described in this paper were collected by one of the authors (D.K.H.). All descriptions are based on formalin - alcohol preserved material; observations of cell content, therefore, are scarce and incomplete.

For electron microscope observations the formalin - alcohol was washed away with distilled water, and a drop of material was mounted on the formvar film of a supporting grid and allowed to dry.

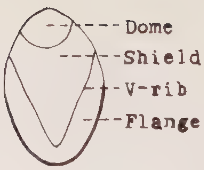
Eight species were found in Alaska; one of them is described as new.

Mallomonas pseudocoronata Prescott

Figs. 2—8

M. pseudocoronata was described and figured by Prescott (1944). He has confirmed that the species found in Alaska is the same as the one from Wisconsin. The following is an extended description of the species.

I. Description as seen in the light microscope. The cell is oval-elliptical, rounded at both poles (Fig. 2). In the preserved material it often appears slightly dorsoventral with a



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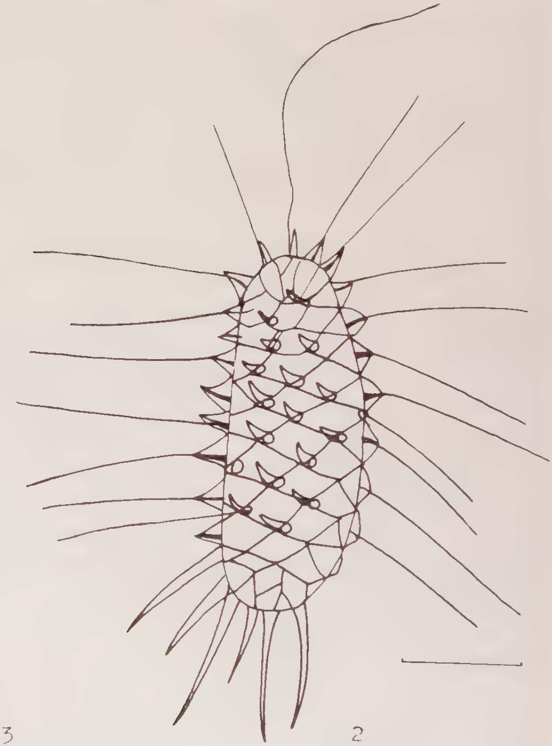

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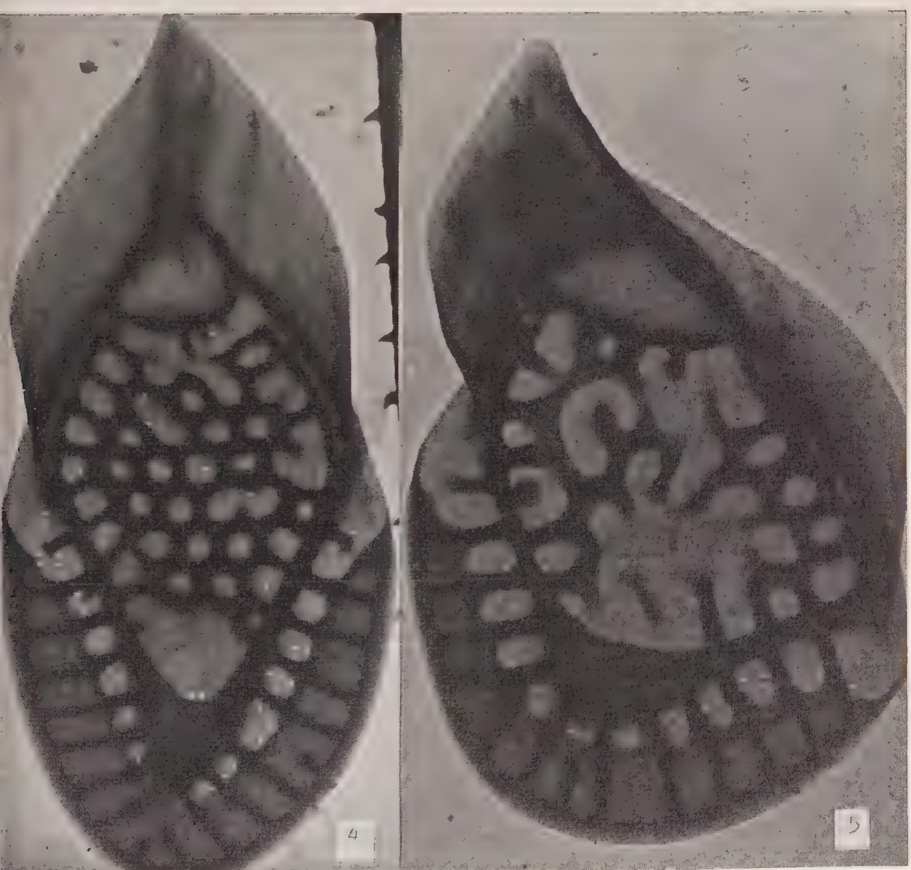
A B C

3

Fig. 1. Tripartite scale as seen in the light microscope.
Fig. 2. *Mallomonas pseudocoronata* as seen in the light microscope. Scale = 10 μ
Fig. 3. *Mallomonas pseudocoronata*. Scales as seen in the light microscope. A. From anterior part of the body. B. Rear-end scale. C. From posterior part of the body. Enlargement as in Fig. 2.

somewhat flattened ventral side. Whether this is the case also in live individuals is not established. Spread over the cell are delicate, slightly curved, smooth, tapering needles (not observed by PRESCOTT). They are rather loosely attached to the scales and are usually lost in the preserved material. Beyond the cell surface protrude short, stout, spine-like, recurved projections which form a „corona" at the anterior end; at the posterior end of the cell is a tuft of stout spines of varying length. The body-scales (Fig. 3 A, C) are imbricate (not observed by PRESCOTT) in spiral oblique series. They are tripartite, the flange is transversely striated, the shield has a more or less well-developed meshwork, and the dome is small and indistinct. The anterior part of the shield and the dome are surrounded by a broad, thin area, the two halves of which curve upwards against each



Mallomonas pseudocoronata. Fig. 4. Apical scale. Fig. 5. Scale from anterior part of the body.

other and protude outwards from the cell forming the above-mentioned spine-like projection. The anterior scales have their long axes longitudinal to the cell. The scales surrounding the apex are short, broad, and asymmetric. The rear scales (Fig. 3B) are small asymmetric, devoid of dome, but in its place they have long, stout spines directed backwards and forming the tail tuft mentioned above.

II. Description as seen in the electron microscope.

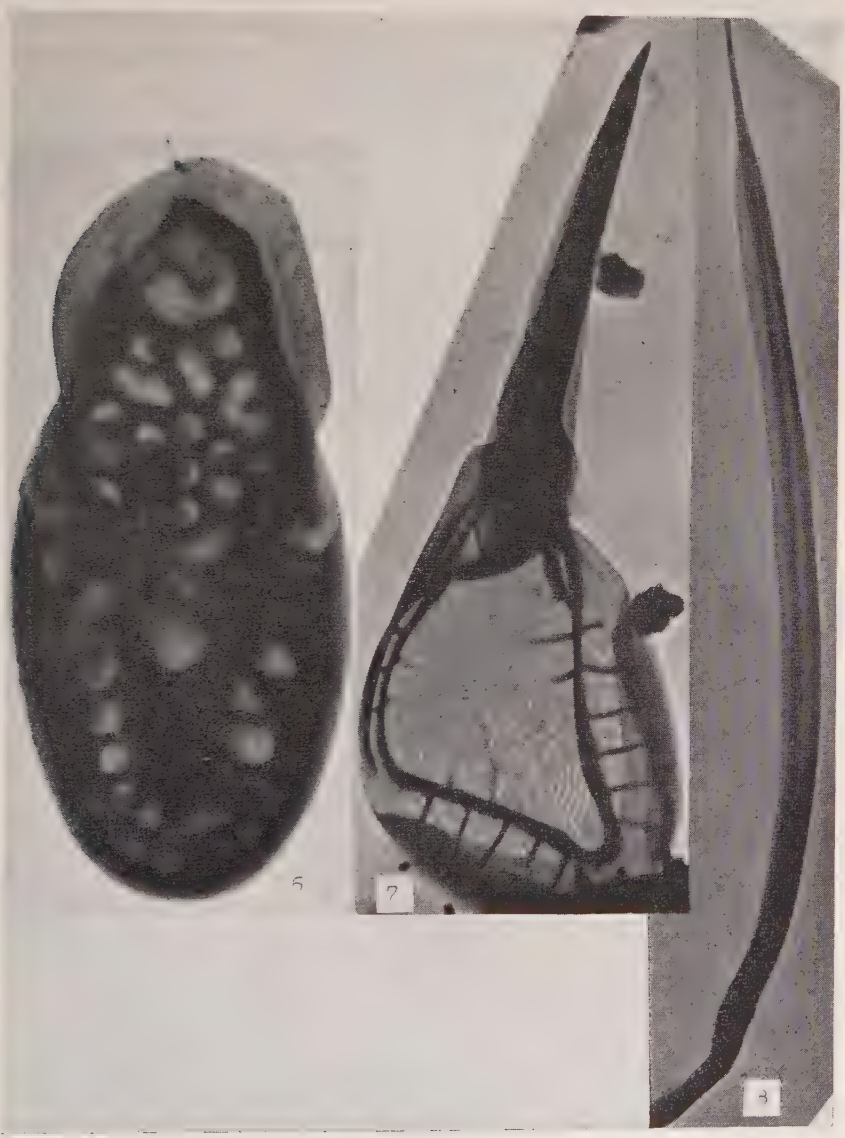
The electron micrographs (Figs. 4—7) show that all ridges are broad and stout, meshes on the shield being nearly circular, and that the perforations of the scale are few and irregularly arranged. Some scales were observed which had larger and more numerous perforations, presumably immature scales. The V-figures of the body scales are regular and acute-angled with a well-developed „roof" between the lower parts of the sides of the V. Along the edge of the flange is a broad folding partly overhanging and obscuring the transverse ribs of the flange. The thin curved area surrounding the front end of each scale projects from the border ribs of shield and dome. It varies in size and shape down the cell. One-half of the dome has minute, irregularly-placed perforations of varying shape. As in many *Mallomonas* species, the bristle (Fig. 8) consists of a thin curled plate. It narrows rather abruptly a short distance inside its blunt tip.

Little is known about the cell content. A few observations suggest that the chromatophore is deeply divided into two lobes. The flagellum is somewhat longer than the cell.

Dimensions: Cell-length (exclusive of spines) 16—35 μ x 7—14 μ, body scales 8—12 μ x 5—7 μ, rear scales (exclusive of spines) 5—6 μ x 4—4.5 μ, rear-end spines 5—12 μ, bristle 13—25 μ.

The species was found as plankton organism in Karluk Lake on Sept. 6th, 1957, at 11.7°, and on Sept. 21st. 1958, at 8.3°, most abundant on the latter date. Both samples contained a pronounced diatom-flagellate association. Dominant was *Asterionella formosa* HASS. Other important associates were *Tabellaria flocculosa* var. *pelagica* HOLMBOE emend. TEILING, *Cyclotella bodanica* EULENST., *Stephanodiscus astraea* (EHR.) GRUN., *Fragilaria capucina* DESMAZIÈRES, *Ceratium hirundinella* SCHRANK, *Mallomonas elongata* REV., *Mallomonas acaroides* var. *crassisquama* ASMUND, and the following Desmidiaceae in order of dominance: *Cosmarium phaseolus* BRÉB. var. *alaskana* CROASDALE, *Spondylosium planum* (WOLLE) W. & G. S. WEST, *Staurodesmus cuspidatus* (BRÉB.) TEILING f. *alaskanus* CROASDALE, *Staurastrum lunatum* RALFS var. *planctonicum* W. & G. S. WEST, *Staurastrum pendulum* NYGAARD var. *pinguiforme* CROASDALE, *Staurastrum petsamoense* JÄRNEFELT var. *minus* f. *kar-*

lukense CROASDALE, and *Staurastrum sebaldi* REINCH var. *impar* CROASDALE.



Mallomonas pseudocoronata. Fig. 6. Scale from posterior part of the body. Fig. 7. Rear-end scale. Fig. 8. Bristle.

Mallomonas corymbosa n.sp.

Figs. 9—12

Diagnosis: Cellula oblonge ovata vel elliptica, in anteriore dimidia parte vel duabus partibus setis vestita. Setae rectae vel subcurvae, dimorphae: alterae gregem anteriorem formantes breviores, crassiores, per totam longitudinem dentium serie unica armatae; reliquae longiores, tenuiores, acutiores, in parte basali longiore vel breviore laeves, supra dentium serie apicem paene attingente armatae, sub ipso apice paulum deflexo dentem unicum ceteris longiorem tenuiorem, acutiorem, extra seriei ordinem situm gerentes. Squamae mediae partis ovales, tripartitae, crista v-formi regulari, acuta; apicales minores, angustiores, cupula pro ratione maiore: posterae cupula destitutae, ultimae perparvae; mediae lineas spirales, anticae et posticae longitudinales formantes. Chromatophorum profunde bifidum. Interiora cetera ignota. Cysta ignota.

Mensura: Cellula 40—52 μ x 9—12 μ, setae anteriores 21.6—32.3 μ, ceterae 34.5—54.7 μ, squamae 5.8—7.2 μ x 3.4—5 μ.

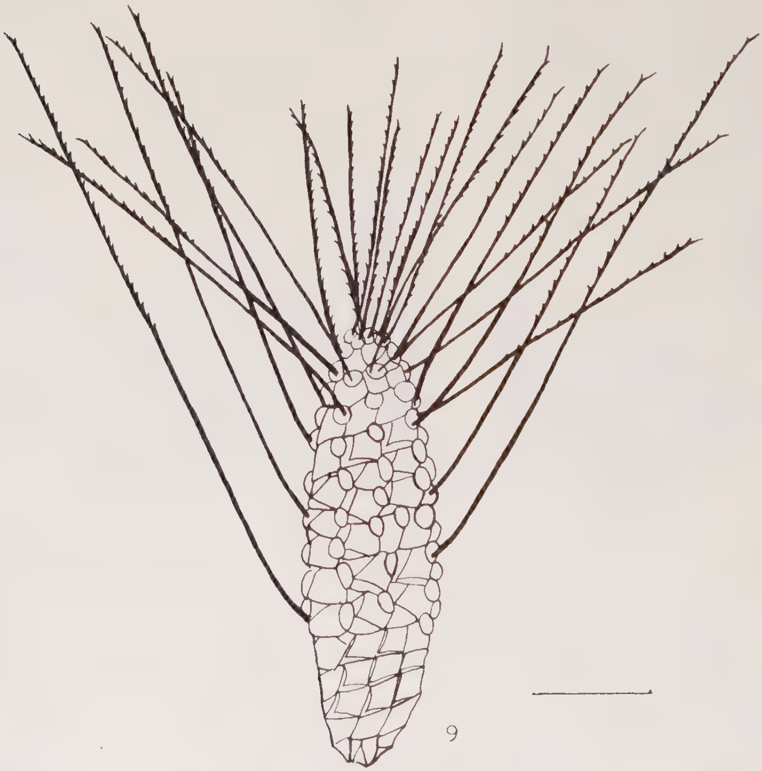


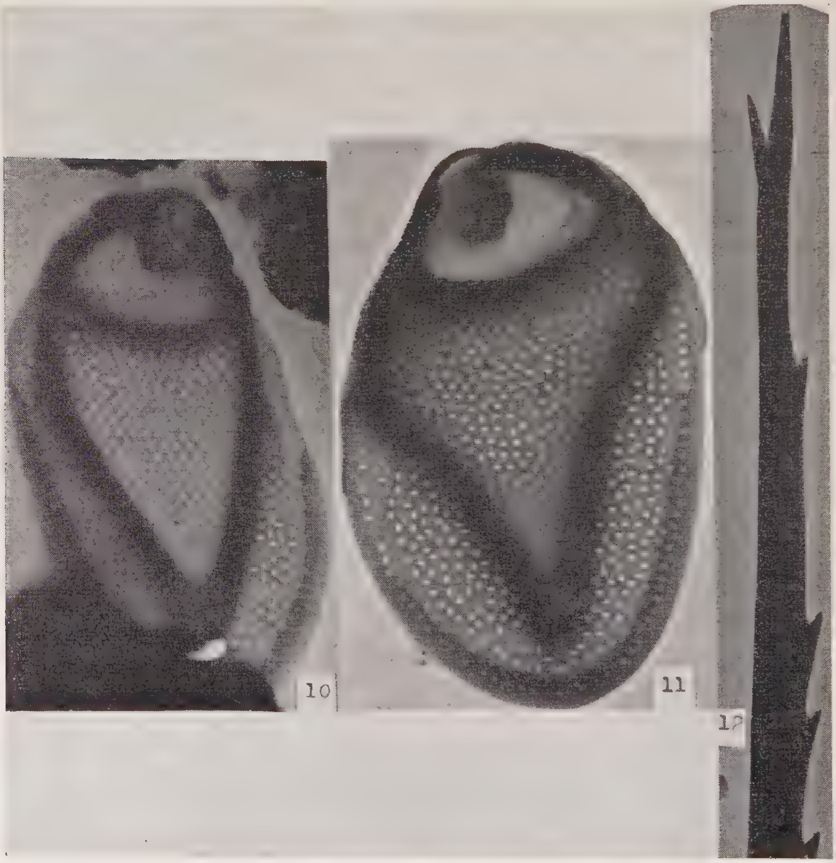
Fig. 9. *Mallomonas corymbosa* as seen in the light microscope. Scale = 10 μ.

Typus die 19. Sept. 1959 in lacu alascano Susitna Lake (lat. bor. 62°23', long. occ. 146°21', altit. supra mare 722 m) lectus, in Museo Botanico Hauniensi depositus.

The diagnosis refers only to light-microscope observations. The following description also includes electron-microscope observations. The cell (Fig. 9) is oblong ovoid or elliptical. The anterior half to two-thirds of it is bristle-bearing. The shorter and broader anterior bristles are unilaterally denticulated from base to tip. The longer, more slender, and more pointed body bristles (Fig. 12) have a smooth proximal part of varying length, a unilaterally denticulated middle part and a short, tapering distal part which is slightly bent and twisted and bears a single tooth a short distance below the tip. This tooth is longer and more acute than the teeth of the denticulation, and points in another direction. In the electron micrographs is seen that the apices of bristles and teeth may be slightly bifurcated. The posterior bristles are usually lost in the preserved material, while the anterior ones remain, presumably a consequence of the difference of the structure of the domes. The remaining bristles are directed obliquely forwards, giving the species a very characteristic appearance.

The tripartite scales vary in size, shape, and structure along the cell. The middle scales (Fig. 11) are large and broad with relatively small and flat domes that are triangular in outline and surrounded by low ridges. Towards the front end the scales (Fig. 10) become successively narrower and more rectangular, with relatively larger more circular and more convex domes surrounded by prominent ridges. These features of the domes may be the reason why the bristles are more solidly affixed to the anterior scales than to those of the middle part of the cell. The posterior scales are devoid of domes and become smaller posteriorly. All domes project considerably above the cell surface, giving the bristle-bearing part of the cell a rough outline, while the posterior domeless part appears smooth. The electron micrographs show that the scales have densely spaced, transverse arrays of minute circular perforations. On the bottom plate of the scales is deposited a well-developed secondary layer (as in *M. tonsurata* TEILING, see ASMUND 1959) in the shape of a very fine-meshed network, the meshes of which surround the perforations and are consequently arranged in the same pattern. Part of the bottom plate may be visible through a „window" in the secondary layer near the base of the shield. The V-figure is acute -angled and regular with slightly concave sides, usually covered by the secondary layer. The flange is broad with a folded edge. Short ribs may be present under the edge of the folding. The anterior part of the dome has a group of rather large circular pores obviously not penetrating the dome. The rest of the dome has minute perforations.

M. corymbosa is closely related to *M. tonsurata* and might be considered a variety of that species. Its most distinctive features are the much larger size of cell, scales, and bristles, the denticulation of all bristles, and, as seen in the electron microscope, the group of pores on the dome. The latter character, however, may be a local variation of no taxonomical value. *M. corymbosa* was found in Lake Louise and Lake Susitna on Sept. 19th, 1959, at 12° and 13°, respectively.



Mallomonas corymbosa. Fig. 10. Apical scale. Fig. 11. Scale from middle part of the body. Fig. 12. Distal part of bristle.

Some important associates in Lake Susitna were: *Asterionella formosa* HASS., *Tabellaria flocculosa* var. *pelagica* HOLMBOE emend. TEIL., *Cyclotella bodanica* EULENST., *Fragilaria crotonensis* KITTON, *Coscinodiscus lacustris* GRUN., *Dinobryon divergens* IMHOF, *Ceratium hirundinella* SCHRANK, *Anabaena flos-aquae* (LYNGB.) BRÉB.,

Aphanizomenon holsaticum RICHT., *Gloeotrichia echinulata* (SM. ET SOW.) RICHT., *Gomphosphaeria lacustris* CHOD., *Anacystis incerta* (LEMM.) DR. ET DAILY, *Arthrodesmus incus* var. *extensus* ANDERSS., *Staurodesmus dejectus* (BRÉB.) TEIL., *Staurodesmus cuspidatus* (BRÉB.) TEIL. var. *maximus* W. WEST, *Staurastrum anatinum* COOKE et WILLS, and *Staurastrum pingue* TEIL.

MALLOMONAS ELONGATA REVERDIN
Figs. 13—14

Electron micrographs of *M. elongata* REVERDIN are described by ASMUND (1959) on the basis of material from Lago Maggiore in Italy and Almind Sø in Denmark. It is rather numerous in the material from Karluk Lake collected on Sept. 6th, 1957, at 11.7°, on Oct. 31st., at 1.7° and less abundant on Sept. 21st, 1958, at 8.3°. The associations of Sept. 6th and Sept. 21st are described above (see *M. pseudocoronata*), while on Oct. 31st a diatom association, dominated by *Asterionella formosa* and *Tabellaria flocculosa* var. *pelagica*, prevailed. A colonial green alga (*Tetraspora*?) with spherical cells imbedded in mucilage is common. At least four species of

Mallomonas elongata. Fig. 13. Scale. Fig. 14. Distal part of bristle.

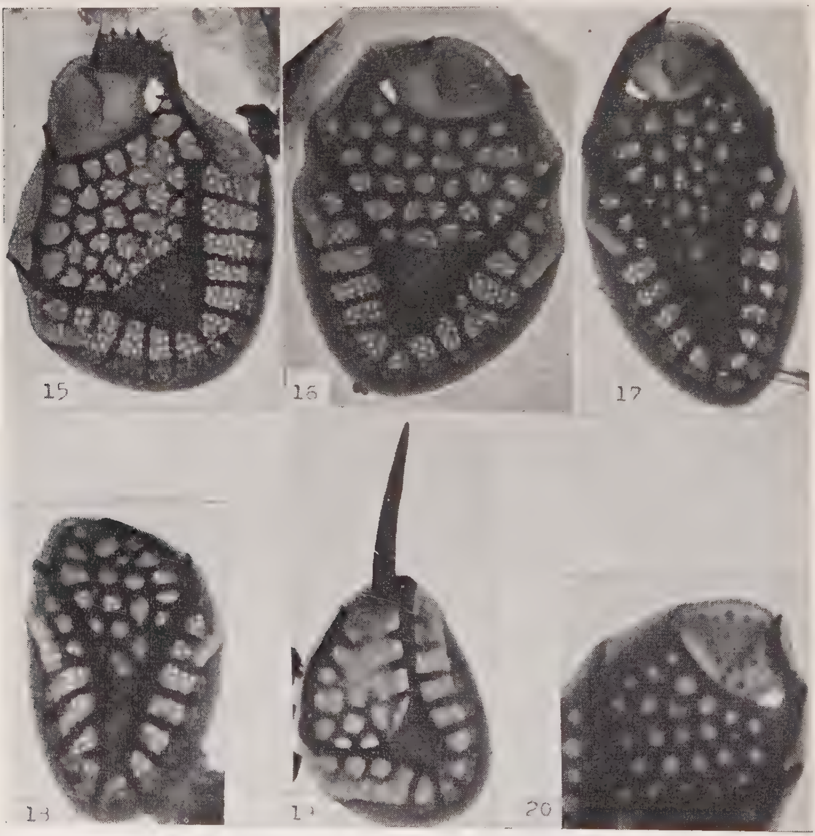
Staurastrum are present. *M. acaroides* var. *crassisquama* and *Peridineum Willei* H. -KAAS appear frequently.

M. elongata appears to be a pronounced lake-form preferring slightly alkaline, oligotrophic to slightly eutrophic water.

MALLOMONAS ACAROIDES VAR. CRASSISQUAMA ASMUND

Figs. 15—22

The electron micrographs of this species were described by ASMUND (1959). Figs. 15—19 show the variation in the scales from apex to posterior end of the cell. Small protuberances on the domes of scales from Karluk Lake (Fig. 20), Oct. 31st. 1957, may be inter-



Mallomonas acaroides var. *crassisquama*. Fig. 15. Apical scale. Fig. 16. Scale from anterior part of the body. Fig. 17. Scale from middle part of the body. Fig. 18. Scale from posterior part of the body. Fig. 19. Rear-end scale. Fig. 20. Anterior part of a scale showing protuberances on the dome.

preted as a temporarily occurring variation. Similar structures in other populations indicate that this feature may be potentially present in every population. The bristles are trimorph. Figs. 21 and 22 show a denticulate body bristle and a helmet one; besides, there may occur shorter and stouter denticulated apical bristles with a shorter distal end outside the extreme tooth of the denticulation. The relative numbers of these types of bristles vary considerably with localities and dates. The reason for this variation is unknown. HARRIS (in lit.) has suggested that it is a question of maturity of cells. The occurrence of the two bristle types in Alaska does not immediately support this assumption. Further investigations are needed to resolve this situation.

Mallomonas acaroides var. *crassisquama*. Fig. 21. Distal part of denticulated bristle. Fig. 22. Distal part of helmet bristle.

M. acaroides var. *crassisquama* was found in the following localities:

Ponds near Anchorage.

Rather numerous in pond I on Nov. 20th, 1957, at a water temp. of 8.6°. The association dominated by *Dinobryon cylindricum* IMHOF; other *Dinobryon* spp., *Chrysolykos planctonicus* MACK, and *M. akrokomos* RUTTNER. Very numerous on Dec. 5th, 1957, at 0.3° in a *Dinobryon cylindricum* - *M. acaroides* var. *crassisquama* - *Synura spinosa* KORSCH. - *Synura echinulata* KORSCH. association. Rather numerous on Nov. 28th, 1959, (temp. not measured). *Dinobryon cylindricum*, *Dinobryon* sp. (*D. elegantissimum* BOURR.?), *Synura spinosa*, and *Synura Petersenii* KORSCH. were common associates. In these samples only a few helmet bristles were observed.

In pond II it was rather common on May 5th, 1957, at 12.2°. No helmet bristles were found. Important associates were *Dinobryon suecicum* var. *longispinum* LEMM., *Dinobryon Borgei* LEMM., *Kephyrion* and *Pseudokephyrion* spp. Very numerous on June 18th, 1957, at

21.8°. A few individuals with one or two helmet bristles. The association dominated by *Dinobryon divergens* IMHOF, other *Dinobryon* spp., and *Kephyrion* and *Pseudokephyrion* spp. Numerous on Nov. 28th, 1959, (temp. not measured). No helmet bristles. *Synura echinulata* one of the most important associates.

In pond IV it was present in small numbers on June 6th, 1957, at 21.8°. Only helmet bristles were found. The association consisted mainly of Chrysophyceae with *Dinobryon divergens* as dominant. On Dec. 5th, 10th, and 19th at 0.3° it was a member of Chrysophyceae associations dominated by *Dinobryon sertularia* EHRB. It was infrequent, and no helmet bristles were found.

Karluk Lake.

Present in rather small numbers on Sept. 6th, 1957, at 11.7°, on Oct. 31st, 1957, at 1.7°, and on Sept. 21st, 1958, at 8.3°. Few helmet bristles were found. The associations of Sept. 1957 and 1958 are described under *M. pseudocoronata*, the association on Oct. 31st contains almost the same species.

Its distribution in Alaska stresses the impression given in an earlier paper (ASMUND 1959) of *Mallomonas acaroides* var. *crassisquama* being a wide spread, very adaptive form.

MALLOMONAS PAPILLOSA HARRIS

M. papillosa was described by HARRIS (HARRIS & BRADLEY 1957) as seen in the light microscope as well as in the electron microscope. It is one of the smallest *Mallomonas* species, and the Alaska form is even smaller than the English one. The scales are tripartite, V-rib regular, obtuse-angled, overhanging the posterior part of the shield (the „hood" of HARRIS). The ornamentation of the scales is less elaborate than in the English form. Papillae of the shield are fewer and less regularly spaced, they are lacking on the dome, and the transverse ridges on the margins near the dome are fewer or often lacking. The domes of the apical scales may be laterally surrounded by raised margins. The delicate bristles are relatively broad, slightly bent and unilaterally denticulated. The individuals from Alaska are covered all over with bristles contrary to the English ones, which show bristles only round the ends. Dimensions: Cell 7—9 μ x 5—6 μ; scales 2—3 μ x 1.5—1.8 μ; bristles 3.5—5 μ.

M. papillosa was found in two of the small temporary pools near Cape Thomson in the summer months. At the time of sampling the temperature was 10°. The occurrence in the arctic region is in accordance with HARRIS's record of it as a stenotherm form (occur-

ring from Nov. until April). The small size of the cell and the scanty ornamentation of the scales may be due to the extreme conditions in arctic pools having acid water and being very poor in nutritive salts. Some important associates are: *Synura* spp., *Fragilaria* sp., *Cylindrocystis Brebissonii* MENEGH., *Closterium acutum* BRÉB., *Closterium striolatum* EHR., *Euastrum bidentatum* NAEG. var. *speciosum* (BOLDT) SCHMIDLE, *Euastrum binale* (TURP.) EHR. var. *Gutwinskii* SCHMIDLE, *Cosmarium subcrenatum* HANTSCH. var. *subsolidum* BOLDT, *Cosmarium Woronichinii* KOSSINSKAJA is dominant.

MALLOMONAS PUMILIO HARRIS
Fig. 23

Electron micrographs of this species were published by HARRIS & BRADLEY (1957) and by ASMUND (1959). The scales of the Alaska specimens differ in the following details from those of the Danish ones: The meshwork of the shield is less developed, not forming the

Fig. 23. *Mallomonas pumilio*. Apical scales and scales from anterior part ot the body.

regular elaborate pattern which characterizes the Danish form. The domes of the bristle-bearing anterior scales are covered by a secondary layer possessing holes larger than the usual scale perforations. Whether it is a matter of developmental, environmental, or taxonomical differences cannot be decided on the basis of the present knowledge.

M. pumilio was abundant in pond IV near Anchorage on Dec. 5th, 1957, at 0.3°, but was scarce in pond I on the same date and at the same temp. The associations of these ponds are dealt with in the description of *M. acaroides*.

Mallomonas akrokomos Ruttner

Figs. 24—27

Electron micrographs of this species are described by Asmund (1956) and by Harris (1958). The Alaska specimens correspond in all details to the previously described specimens. The dimorphy of bristles is very marked. The longer ones (Fig. 24) are slender, tapering to a fine point and unilaterally denticulated. The group of apical bristles consists of shorter, stouter, often bilaterally denticulated bristles with more bluntly pointed, occasionally bifurcated tips. Also the teeth of the denticulation may be bifurcated. Length of short bristles 10—15 μ, of long bristles 21—28 μ.

M. akrokomos was found in pond IV near Anchorage on Dec. 5th, 10th, and 19th, 1957, at 0.3°; and on Nov. 28th 1959; in pond I on Nov. 20th at 8.6°. It is most numerous in the sample from pond IV on Dec. 5th, but also abundant in the other samples. The associates are described under *M. acaroides*.

Mallomonas caudata Iwanoff emend. Krieger

Electron micrographs of *M. caudata* were described by Asmund 1955, 1959) and by Harris & Bradley (1957). Micrographs of the Alaska specimens show the same features as described earlier, but are distinct in showing a roughly rectangular, minute hole near the posterior end of the scale. Insignificant though this feature is, it characterizes the Alaska strain of *M. caudata* and is an example of the fact that almost every local strain of a species has certain features of its own in which it differs from other strains.

Nygaard (1956) and Bourrelly (1957) are of opinion that *M. caudata* Iwanoff has no relation to the species described by Krieger (1930). Nygaard changed the name of Krieger's species into *M.*

Mallomonas akrokomos. Fig. 24. Distal part of bristle. Fig. 25. Apical scales. Fig. 26. Scales from middle part of the body. Fig. 27. „Tail".

fastigata ZACH. and BOURRELLY into *M. fastigata* var. *Kriegeri*. I do not agree with them as to these points of view. IWANOFF'S description (1899) of the very characteristic shape of cell, appearance of bristles, and dimensions of cell and bristles agrees very well with KRIEGER'S description. IWANOFF, however, figured — but did not describe in the text — some tripartite scales and mentioned the presence of branched bristles. But IWANOFF writes, „Die Schuppen

sind häufig ohne Linien und die Nadel ist in einiger Entfernung vom Rande angeheftet"; thus, he has undoubtedly observed the scales later described by KRIEGER. It is my opinion that in his dry preparations IWANOFF has mixed his material of *M. caudata* with the scales of another *Mallomonas* species. Anyone working with dry preparations knows that this may easily happen. IWANOFF's observation of branched bristles is a very understandable misinterpretation in a species so densely covered with bristles as is *M. caudata*. Therefore, I think that KRIEGER is right in identifying his species with *M. caudata* IWANOFF.

The name of *M. fastigata* was first given to a species collected by ZACHARIAS, but described by LEMMERMANN (1898) as differing from all other *Mallomonas* species in having a long tapering posterior end. He did not mention scales and bristles. ZACHARIAS gave later (1903) a closer description of it and — as already suggested by IWANOFF — identified *M. caudata* with it. LEMMERMANN (1904) does not agree with him in this hypothesis, but is of opinion that the two species differ in the shape of their scales, *M. caudata* having oval scales and *M. fastigata* circular scales. As the scales of *M. caudata* in fact vary from oval to circular, the two species cannot be distinguished by this feature. As the description of *M. fastigata* from 1898 is very incomplete the name of *M. caudata* has the priority.

M. caudata was found in rather small numbers in Lake Louise and Lake Susitna on Sept. 19th, 1959.

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The authors wish to express their thanks to Dr. HANNAH CROASDALE of Dartmouth College, for identifying most of the desmids listed herein.

SUMMARY

I. An account is given of the following habitats in Alaska from which species of *Synura* and *Mallomonas* were collected: three

unnamed ponds near Anchorage, Karluk Lake on Kodiak Island, temporary pools near Cape Thomson, and Lake Louise and Lake Susitna (62° 23' N 146° 21' W) The account includes notes on topography, geology, vegetation, temperature, and chemistry at the time of sampling, classification, and phytoplankton content.

II. Description of *Mallomonas pseudocoronata* PRESCOTT and a new species, *M. corymbosa* and reports on six other species from the above- mentioned localities. Electron micrographs of scales and bristles are shown. Notes are made on periodicity, ecology, and sociology.

III. Discussion of the designation of *M. caudata.*

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Paul Smith Welch
(1882—1959)

Paul Smith Welch

1882—1959

PAUL SMITH WELCH, Professor of Zoology Emeritus, at the University of Michigan, U.S.A., died unexpectedly October 1, 1959. Death was due to heart failure. His general health had been good during the preceding summer and he had been one of the major speakers on the Program of the Semi-Centennial Celebration of the University of Michigan Biological Station on Douglas Lake, June 16—19, 1959. The University, Science, and Society suffered a heavy loss in his passing.

Professor WELCH was born January 28, 1882, at Oconee, Illinois. He received the A.B. degree from James Millikin University in 1910; the M.A. degree from the University of Illinois in 1911 and the Ph.D from the same Institution in 1913. In 1955, James Millikin University awarded the honorary Doctor of Science degree to Professor WELCH in connection with the dedication of a new Science Building. During his undergraduate years (1906—1910) he was a student of the late Professor T. W. GALLOWAY and served as Assistant in the William Barnes Lepidoptera Collection. At the University of Illinois, he studied under the direction of the late Professor FRANK SMITH, who not only served as Chairman of his doctoral investigation on the Enchytraeidae of North America, but who also broadened his student's interest in the whole field of fresh-water Biology.

After receiving his Master's degree from Illinois in June, 1911, WELCH spent the next 40 consecutive summers at various Biological Stations and field laboratories. That extensive field experience, which so profoundly affected the nature of his professional publications, began with three summers in succession (1911—1913) at Douglas Lake. He spent the latter part of the summers of 1914, 1915 and 1917 at Douglas Lake, again, but the early part of those three summers at the Marine Biological Laboratory Woods Hole, Mass. (1914 and. 1915) and at the Ohio State University Lake Laboratory (1917). The Summer of 1916 was spent partly at Woods Hole, and the remainder on the Staff of the New York State College of Forestry's Biological Survey of Oneida Lake.

Upon completion of his doctoral dissertation (1913), WELCH joined the Faculty of Kansas State College. He served there, suc-

cessively, as Instructor (1913—14), Assistant Professor (1914—1917) and Associate Professor (1917—18). At the close of the latter year he accepted a call from the University of Michigan and joined the Faculty at Ann Arbor as Assistant Professor of Zoology in which capacity he served until advanced to the rank of Associate Professor 1922. He became Professor in 1928, and Professor Emeritus when he retired in February, 1952.

When, in June 1918, WELCH returned to Michigan, to remain here for the rest of his academic career, he also joined the Staff of the Biological Station and began to modify an older course and reshape its emphasis. Although the process was a gradual one, by the summer of 1922 the character of the revision was so obvious that the name was changed to "*Limnology*" for the session of 1923. In addition to his years of teaching and research at Douglas Lake, WELCH also served there in different administrative capacities. He was Acting Director of the Biological Station during 1924—'25; Assistant Director 1929 and 1930, and a member of the Executive Committee from 1940 through 1949.

PAUL WELCH's teaching and research activities, as well as his scholarly publications, exhibited an interesting evolution. Early in his undergraduate years he became a serious student of the biology of insects. It was only natural that his work in the Barnes Collection of Lepidoptera should increase that interest. His first publications were in the field of entomology and, likewise, the first courses that he taught, both at Kansas State College and at the University of Michigan Biological Station were in the same subject.

The influence of the great invertebrate zoologist, Professor FRANK SMITH, led WELCH into broader areas of scientific knowledge during his years at Urbana and resulted first in his doctoral dissertation on the Enchytraeidae; subsequently in a long series of papers on these and other annelids and eventually in a still longer series in the young and rapidly expanding science of Limnology. It was here that WELCH won his most enduring fame and rendered his greatest service to science. Thirty-seven doctoral candidates earned their Ph.D degree under the kindly but exacting guidance of this man. Their dissertations ranged widely through the three fields of entomology, invertebrate zoology and limnology, but as the years advanced and their chairman's interest, experience and international reputation expanded in the latter area, more and more of his doctoral students found their major opportunity in that same subject. WELCH published more than sixty research articles during his lifetime, several of considerable size and great significance, none trivial. In addition to these contributions, he was author or coauthor of four textbooks and a revised second edition of the largest of these.

Dr. WELCH was a member of more than fifteen national scientific and honorary societies. He held many offices in them, including terms as President of the American Microscopical Society (1928); American Society of Limnology and Oceanography (1949—50). He was a co-founder of the Great Lakes Research Institute and of the Limnological Society of America, which later merged with the oceanographers. Prior to the foundation of this latter organization, WELCH served (1929—34) as a member of the National Research Council Committee on Hydrobiology, which was instrumental in the founding of the Limnological Society. Dr. WELCH also served as Editor of the Papers of the Michigan Academy (1921—1925) and of Transactions of the Microscopical Society (1919—1924). He traveled widely both in North America and in Europe and spent the academic year 1925—1926 visiting European universities and biological stations, where he was already widely and favorably known for his productive scholarship.

PAUL WELCH was characterized by a splendid poise and quiet dignity. Although reserved among strangers, he was warm-hearted, kindly and generous with friends. His students regarded him as an inspiring teacher, with a genuine interest in their intellectual development and distinctly fair in his evaluations. He expected and elicited sincere effort, genuine interest, effective performance and absolute honesty on the part of those whose work he directed, whether undergraduate or doctoral candidate. Among his colleagues he was honored for his integrity, industry and scholarly achievements; respected for his innate wholesomeness in thought and speech, unbiased judgement, and quiet effectiveness; loved for his generosity, modesty and warm human interest in those about him.

Dr. WELCH is survived by his widow, Eva Grace (Miller) Welch, and by their daughter, Anne Louise, who continue to reside at the gracious family home in Ann Arbor, and by a brother, Louis Welch of Florida.

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